POST RADIOLOGICAL INCIDENT DOSIMETRY FOR SEARCH AND RESCUE DOGS

A Dissertation

by

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ABSTRACT

Urban Search and Rescue (USAR) dogs are valuable members of the USAR teams and are deployed in all types of scenarios and conditions. There is a large investment made with each animal in the form of time and money spent on training. In addition, the handlers are often their owners adding a substantial emotional investment. The inability of USAR dogs to wear any protective equipment for safety reasons leaves them especially vulnerable to any contaminants with which they may come in contact. Interestingly, no research has previously been conducted on the radiation doses received by USAR dogs in a scenario with a contaminated environment. This research aims to give USAR handlers more information when deployed to areas contaminated with radiological material. This dissertation describes the computation of external and internal dose rate conversion factors along with calculations of internal dose rate conversion factors and their compilation into a tool for USAR dog handlers called FidoFRMAC. Decay schema for 48 radionuclides of interest were analyzed and the resulting information was used to calculate external dose rate conversion factors using modified equations originally derived for humans. Calculation of the internal dose rate conversion factors used the Federal Radiological Monitoring and Assessment Center (FRMAC) resuspension dose rate conversion factors as a baseline and scaled breathing parameters to adjust for the differences in respiratory systems of the two species. These dose rate conversion factors were assembled into a spreadsheet program with the ability to import data from atmospheric dispersion models such as QUIC and HOTSPOT. The user can select from the radionuclides of interest and

obtain visual representations of the dose rates resulting from the contamination. It is the hope that this research and resulting program will be of use to USAR handlers and will play a small part in keeping these animals safe.

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CHAPTER I

INTRODUCTION AND LITERATURE REVIEW

Introduction

Following a radiological terrorist incident urban search and rescue (USAR) teams may be deployed to search for victims. Personnel protective equipment (PPE) such as coveralls, gloves, and respirators are available for human rescuers. However, only limited PPE is available for search dogs and any sort of muzzle covering would hamper their ability to locate victims. If these animals are called upon to search contaminated areas, they could experience internal contamination through inhalation and ingestion. Because of this potential exposure, USAR dog handlers have many concerns regarding the use of their animals for search operations in contaminated environments. The dogs require a large financial investment in their training and the bond between the animal and handler is quite strong.

Beginning in the 1960s significant research was conducted involving inhalation studies with beagles. These studies were mainly to investigate the possible effects of inhaled radionuclides in humans. The research has some application to USAR dogs, but does not fully simulate the working conditions of these animals. The research described herein will examine potential doses received by USAR dogs in radiologically contaminated environments. By working in conjunction with the College of Veterinary Medicine & Biomedical Sciences at Texas A&M University, and using ICRP methodology, approximate doses can be calculated. These dose estimates can be used by health and safety personnel to avoid acute effects and reduce the risk of long-term effects in these very valuable animals.

This research consists of several parts – 1) investigate existing regulations and procedures already in place for USAR dogs, 2) Reconstruct dispersal events employing NCRP guidance for dose reconstruction using the QUIC-Plume code from Los Alamos National Laboratory to understand the mechanisms of dispersion from radiological dispersal devices (RDDs) (NCRP 2008), 3) determine dose rate conversion factors of both internal and external exposure pathways. These factors will be compared to the resulting dose rates and subsequent doses to thresholds from literature known to produce radiation-induced effects and 4) produce a spreadsheet that can be used as a USAR dog dose calculation tool. Data from this spreadsheet can be employed to generate visual representations of dose rates and can be used to generate iso-dose curves on search area maps. These capabilities will allow handlers to anticipate any hot spots and areas of concern.

Literature Review

While nuclear terrorism is an ever-present threat, it is believed that terrorists are more likely to use an RDD, compared to an improvised nuclear weapon. Often referred to as a "dirty-bomb" an RDD usually combines conventional explosives with radioactive materials such those used in medicine, industry and research. The size of the affected area and the level of destruction caused by an RDD would depend on the sophistication and size of the conventional bomb, the type of radiological emissions, the chemical form and the quantity of the radioactive material. In addition, local meteorological conditions (primarily wind speed, wind direction and precipitation) will also play a part. The area affected could be placed off-limits to the public for several months during cleanup efforts (DHS 2012). With these threats of terrorist attacks, the issue of monitoring USAR animals is a current topic of interest in emergency response circles. To first response team members and the handlers, USAR dogs are not merely working animals but are family pets and valuable team members that perform important tasks during their rescue missions.

While other hazards have been studied, there has been very little done to determine the effects of radiation on USAR dogs. Murphy and Gwaltney-Brant have discussed how recent terrorist events in New York, Washington D.C., and Pennsylvania highlighted the role USAR dogs play (Gwaltney-Brant 2003). After these events, the affected areas became contaminated with many toxic agents such as phosgene gas and asbestos. The affects from these materials are examined further in the article explaining how specific agents such as hydrocarbons, hazardous metals and gases can hinder the completion of a rescue mission and cause issues in the long-term health of the dog (Guilmette 1987, Machpherson 2014). These effects must be known by the veterinarian in the field and are discussed by Jones (Jones 2004). These articles focused only on chemically toxic agents, not radiation. If USAR dogs are deployed to a radiological event such as an RDD, the animals will be exposed to the material through several different pathways. The predominant methods will be through the inhalation of resuspended material and the external exposure from material deposited on surfaces (Walsh 2002). While both pathways result from atmospheric dispersion, these have very different impacts. Deposited material is important in determining external radiation dose, while resuspension affects the breathable concentration and therefore the internal dose (Nicholson 2002).

The mechanisms responsible for resuspension are complex and have been studied as far back as the 1940's with an interest in erosion and soil transport. Shortly after the advent of nuclear technologies, that research transformed into an interest in the health effects from the resuspension and deposition of material related to weapons testing and releases from the nuclear power industry (Nicholson 1987). Since then, many experiments have been performed and several review articles published on studies regarding the Nevada Test Site, the United Kingdom, and areas impacted by Chernobyl (Walsh 2002, Sehmel 1988, Nicholson 1987). Research by Nicholson, evaluated these studies and their shortcomings. His research focused on the general aspects of the experiments themselves rather than numerical results. He also discussed resuspension by means other than wind. The review article by Sehmel however summarized numerical values of resuspension variables, rates, factors, and weathering half-lives. His research showed the great uncertainties in predicting resuspension, showing resuspension factors that varied from 10^{-10} to over 10^{-2} m^{-1}, and weathering half-lives from 35 days to years (Sehmel 1988). Walsh, whose article focused on emergency response, reviewed two types of resuspension methodologies suitable for use in the United Kingdom. In addition, tables of the activity concentration in air due to resuspension and integrated doses due to the inhalation of resuspended air concentrations as a function of time, are presented. The uncertainties associated with estimates of the activity concentration in air due to resuspension are discussed (Walsh 2002).

Lynn Anspaugh, author of articles on modeling resuspension, presents models in his articles that can be used to estimate resuspension concentrations as a function of time as well as changes in the concentration of material changes as a function of height (Anspaugh 1975a, 2011). The use of these models has previously been explored by environmental scientists concerned with the atmospheric transport of material. Anspaugh's research will be used in the research proposed here to help make predictions about material concentrations in the breathing zone of USAR dogs.

There have been many studies on the inhalation of radionuclides in dogs. Papers such as those written by Muggenburg et al. give some insight into the radiation-induced effects that occur with the inhalation of radioactivity in the body of beagles (Hahn 1983, Muggenburg 1999). Norris et al. gives a detailed examination of the dogs by clinical methods, hematology, blood biochemistry and the gross and microscopic inspection of tissues leading to the complete expression of the biological response versus gamma radiation (Norris 1968). Blair et al. gives an extensive list of the effects of alpha-radiation and the average doses at which the consequences are believed to become issues (Blair 1989). Guilmette et al. describe the uptake and retention of $^{239}PuO_2$ in the tissues of dogs that received single inhalation exposures to monodisperse aerosols of $^{239}PuO_2$ (Guilmette 1987). Park et al. took seven groups of beagles exposed to $^{239}PuO_2$ aerosols by inhalation and observed them throughout their lives to determine tissues at risk and dose-effect relationships (Park 2012). Hahn et al. in their study investigated the different radiation dose patterns in the lung from inhaled beta-emitting radionuclides and the influence these radionuclides had on severity and frequency of biological effects (Hahn 1983). While the available literature is somewhat applicable to the inhalation of radioactive material in typical dogs, none of the past research considered the unique working conditions of USAR dogs. Previous studies utilized nebulizers, aerosol chambers, and occasionally placing radioactive material into the lungs of animals under anesthesia. The research proposed here aims to explore the amount that is inhaled by the animals in the working conditions anticipated to be encountered.

While there have yet to be articles written about the doses received by dogs in emergency response, Kocher has published several articles for humans. In his research, he calculated dose rate conversion factors for radionuclides that would be encountered during releases from nuclear facilities in several source-to-receptor configurations. The most relevant configuration involves irradiation at one meter from radioactive materials deposited on the ground (Kocher 1981, Kocher et al. 1983, 1985). These articles by Kocher et al. can be used to present equations that can be used to calculate doses at various heights above the ground for monoenergetic photons and electrons. These methods assume an infinite, uniform deposition of radionuclides. In the case of photon emissions, the well-known photon point kernel equation is used. Point kernel equations for beta radiation do not exist, as a result scaled point kernels must be used instead (Berger 1973). Berger developed a calculation of the spatial distribution of absorbed dose in a water medium around monoenergetic, point-isotropic, electron sources, taking into account multiple Coulomb scattering by atoms and orbital electrons (Berger 1973). The transport of energy from secondary bremsstrahlung was also included. This research resulted in point kernels for 36 source energies between 0.5 keV and 10 MeV with the distance in units of electron range. While this research was done exclusively for humans, these data can be used as a starting point for calculating dose rate conversion factors for USAR dogs. The similarity in geometry allows for only adjustments in height to be made, making this a straightforward calculation.

The effects of radiation on dogs have been studied for decades. These studies were performed on dogs as a surrogate for human trials with the hopes of learning more about the possible effects from inhalation of material and nuclear weapon effects. The sources used were often actinides or gamma emitters. Many of these experiments were inhalation studies, as a result there is a plethora of information on the effects to the lung and lymphatic system. Fig 1-2-1-9 show the effects observed after exposure to plutonium as described by Bair et. al (Bair 1989). The severity of the effects was graded on a scale from 1 to 5.

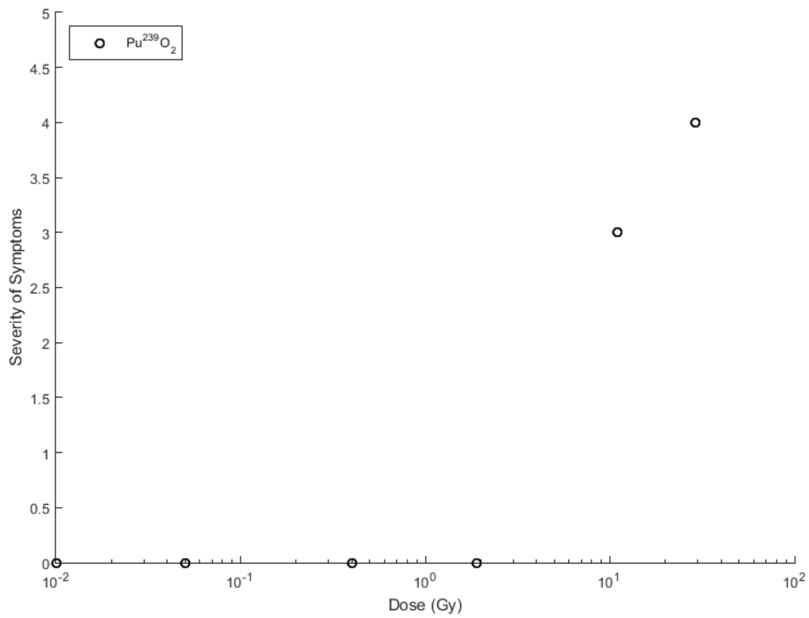

Figure 1-1 Observed severity of hepatic centrilobular congestion as a function of dose from aerosols of several $Pu^{239}O_2$

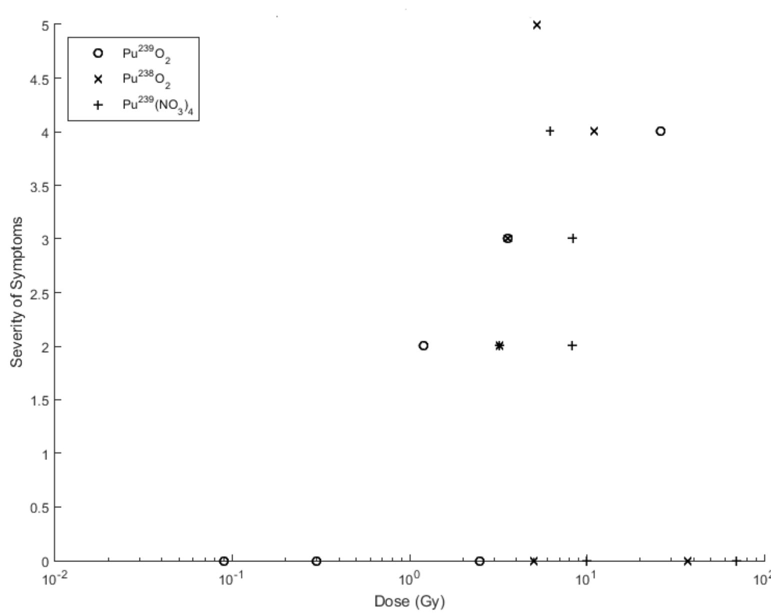

Figure 1-2 Observed severity of lymphopenia as a function of dose from aerosols of several plutonium isotopes

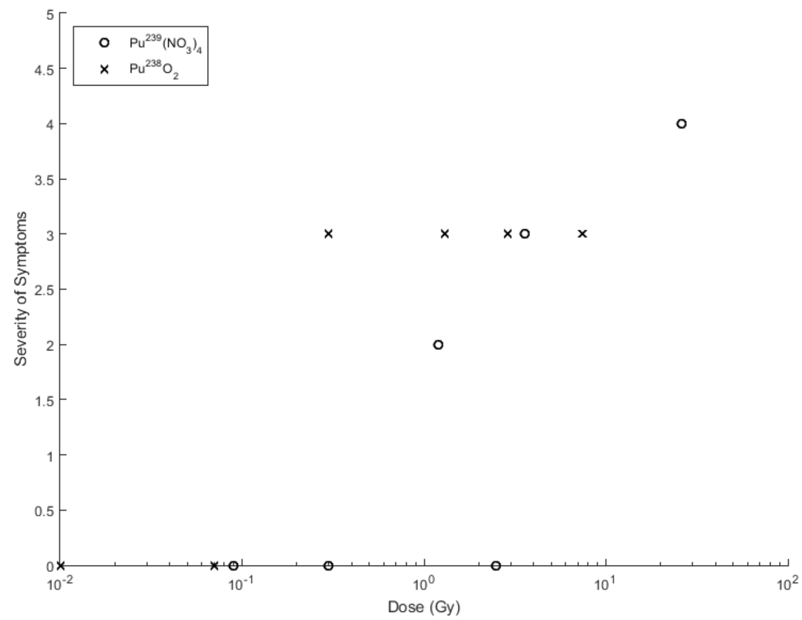

Figure 1-3 Observed severity of liver degeneration as a function of dose from aerosols of several plutonium isotopes

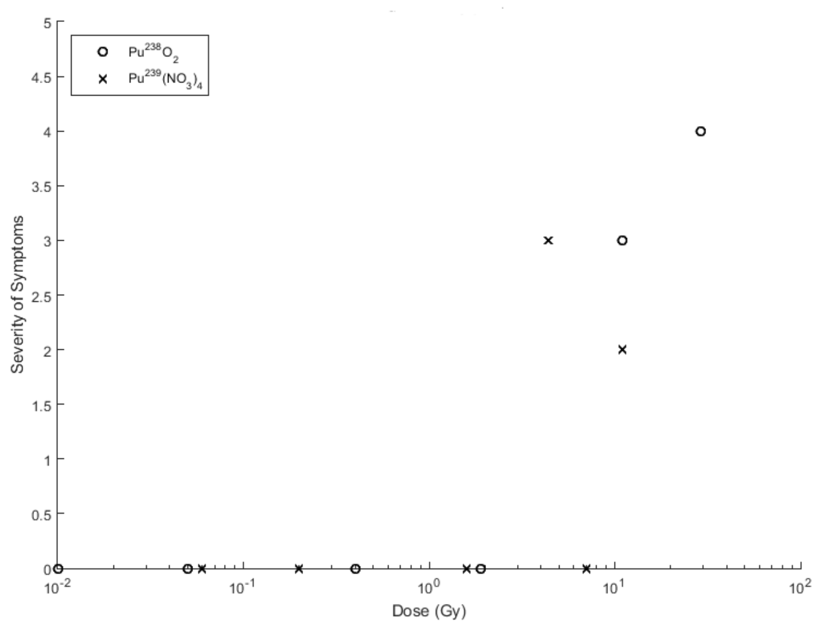

Figure 1-4 Observed severity of radiation osteodystrophy as a function of dose from aerosols of several plutonium isotopes

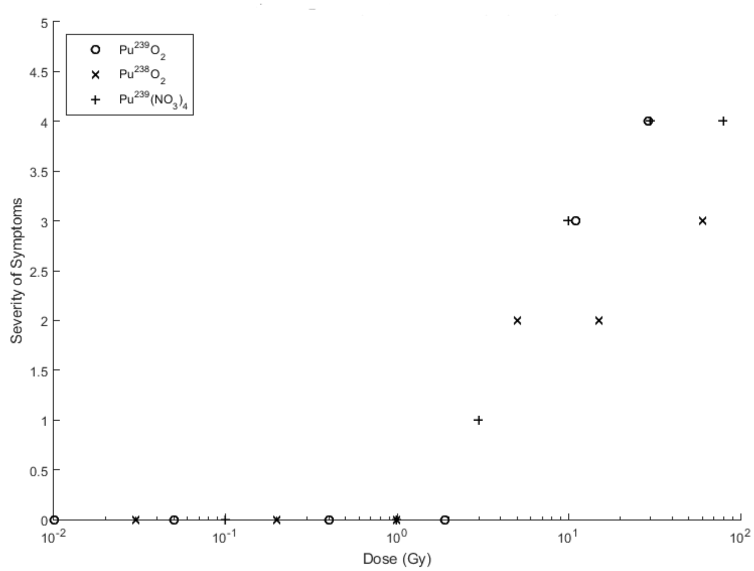

Figure 1-5 Observed severity of radiation pneumonitis as a function of dose from aerosols of several plutonium isotopes

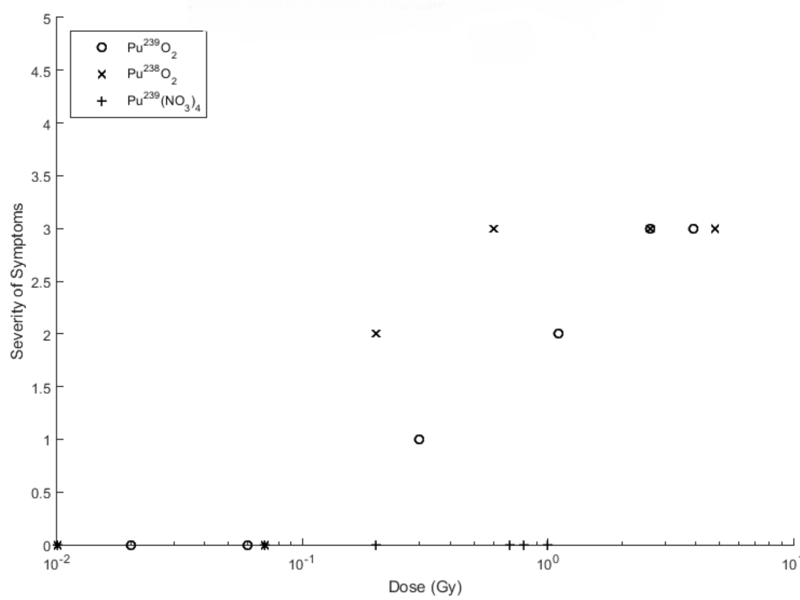

Figure 1-6 Observed severity of SGPT as a function of dose from aerosols of several plutonium isotopes

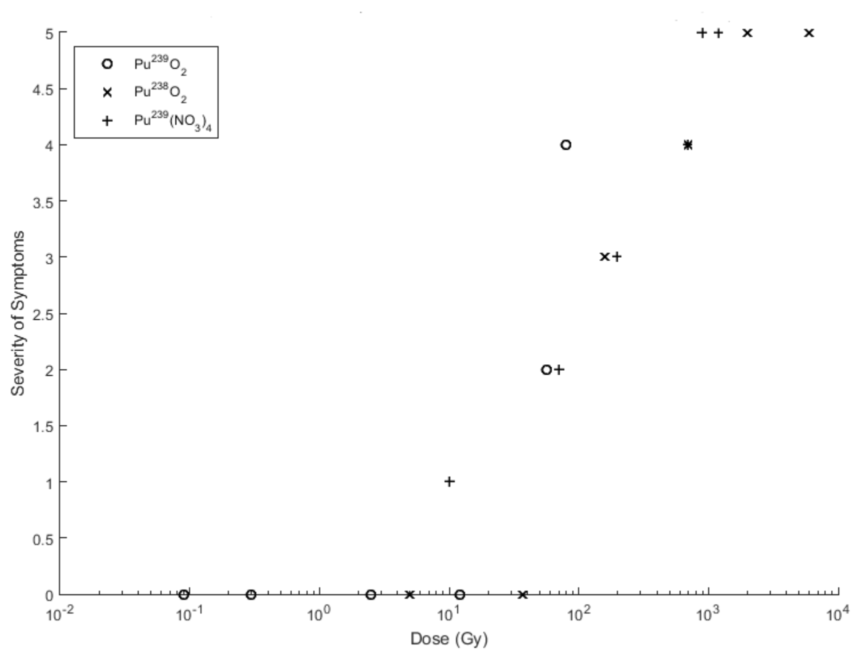

Figure 1-7 Observed severity of the sclerosis of the tracheobronchial lymph nodes as a function of dose from aerosols of several plutonium isotopes

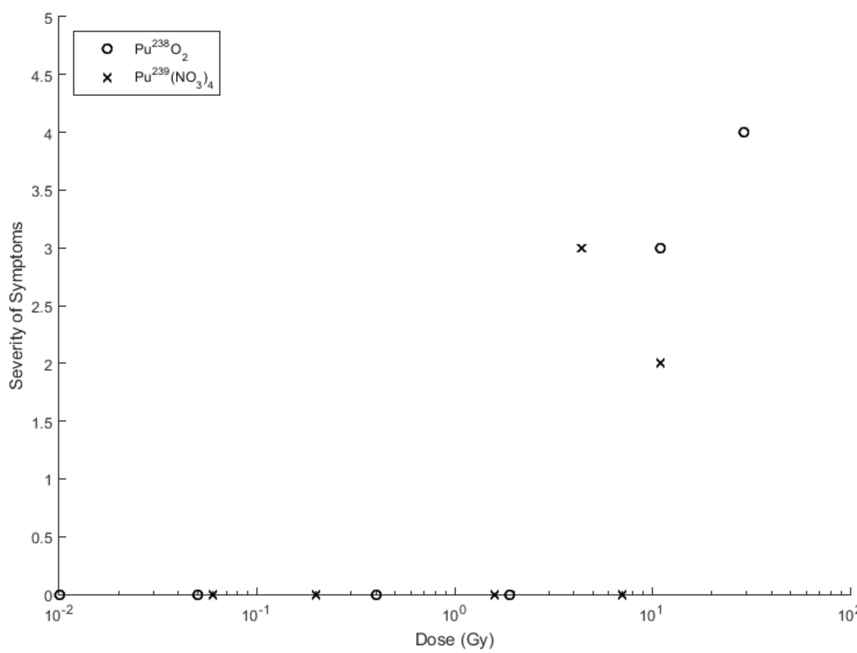

Figure 1-8 Observed severity of radiation pneumonitis as a function of dose from aerosols of several plutonium isotopes

While acute effects were not the primary objective of these studies, there were occasions in these trials where acute effects were observed. The effects and thresholds are presented in Table 1-1.

Table 1-1 Acute radiation effects observed in dogs and their thresholds

Effect	Threshold	Reference
Significant lymphopenia	25 R	Prosser 1947
60% Reduction in Leukocytes	50 R	Prosser 1947
Anemia	100 R	Prosser 1947
Absence of Reticulocytes	200 R	Prosser 1947
20%-40% destruction of Red Blood Cells	200 R	Prosser 1947
Increased Sedimentation Rate	100 R	Prosser 1947
Increased Clotting Time (x2-x4)	200 R	Prosser 1947
50% Increase in Heart rate and 2° increase in rectal temperature	250 R	Prosser 1947
LD_{50}(30 Days) 15 R min^{-1}	258 R	Norris 1968
LD_{50}(30 Days) 6 R min^{-1}	358 R	Shively 1958

According to the European Nuclear Society, the thresholds for human instances of erythema, cataracts, and permanent sterility are 3 Gy, 2 Gy, and 2.5 Gy, respectively (ENS 2016). While it is believed that effects to the dogs such as epilation and erythema will be similar in nature to those that occur in humans, information on their thresholds was limited and it is unknown whether similar thresholds will exist.

Stochastic effects are those in which the chance of occurring increases with dose. These include cancers and hereditary effects. Some breeds of USAR dogs are predisposed to certain types of cancers as shown in Table 1-2 (Dobson 2012).

Table 1-2 Predisposed cancer risks of USAR dog breeds, adapted from Dobson 2012

Breed	% chance of dying of cancer	% in survey population	Ratio	Tumor types for which breed has been reported to be at risk
Golden Retriever	8.91	7.16	1.2	Mast cell tumor, lymphoma, oral melanoma, fibrasarcoma, histiocytic tumors
Labrador Retriever	11.58	11.45	1.0	Mast cell tumor
German Shepherd	8.46	10.02	0.8	Haemangiosarcoma

Calculating the risk of cancer from radiation is a complex process involving highly precise risk coefficients. The Pacific Northwest National Laboratory and the Lovelace Respiratory Research Institute have both previously conducted research to determine risk coefficients for dogs that inhaled $^{238}PuO_2$. Their findings showed that their derived risk estimates for lung and bone tumors were consistent with estimates used in radiation protection (Gilbert 1998). The most conservative model for estimating risk is the Linear

No Threshold model, however, there are data suggesting that the threshold model is a more accurate portrayal of the real situation. In addition there are data that shows low doses of radiation to have a hormetic effect. Fig. 1-9 shows the three models as a function of dose. Risk coefficients derived from animal and human data are remarkably similar (Recio 2010).

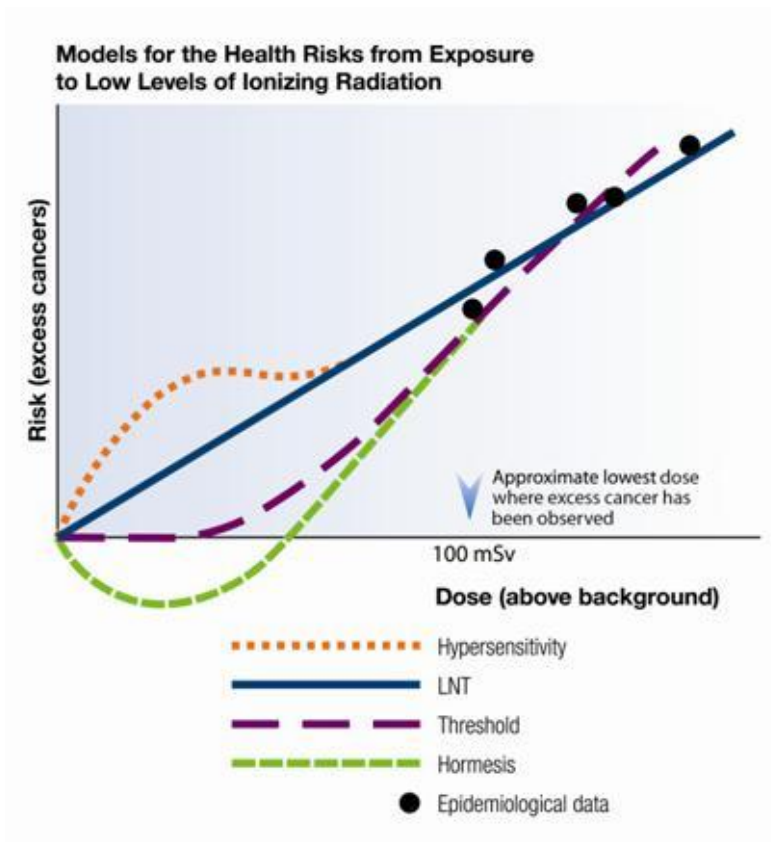

Figure 1-9 Graphical representations of current radiation risk models as a function of absorbed dose (Canadian Nuclear Safety Commission 2015)

Methods and Materials

The first aspect of this research collected any protocols or procedures already in place for USAR animals under working conditions. Through the Texas A&M Engineering Extension Service (TEEX) Disaster City Training Center, a nationally recognized USAR training institute, contact information was obtained for local members of the Texas Task Force 1 response team. These individuals provided the standard USAR dog protocols for different scenarios. The following questions were posed for each contact in September of 2013 (Macpherson 2014):

1. What is the concept of operations for handling a USAR dog under perfect conditions?
2. How do these rules change as conditions change?
3. Are there standard operations and procedures that are followed? If so, what is the source containing these operations and procedures?

These responses helped define variables that were valuable when performing dose assessments for the animals.

The second part of this research defined the exposure scenarios and identified the exposure pathways. An exposure scenario is a conceptual representation of an exposure situation of concern that provides the basis for a dose reconstruction. The scenario for this research is the detonation of a RDD in an urban setting. Of major importance in this reconstruction is understanding how the resulting particle distribution and radiation field influences the doses received and ultimately the possible effects arise from these doses. Using the QUIC-Plume, code developed by Michael Brown at Los Alamos National Lab, an urban environment was used in the simulated detonation of an RDD. The resulting particulate distribution and radiation field were also determined (Brown 2009).

To understand how the doses are received, exposure pathways must be understood. The scenario to be studied is a RDD detonation that disperses particulate matter and creates widespread contamination. The exposure pathways are internal intakes through inhalation, ingestion, as well as external exposure. Calculations of the internal intakes involve evaluating the type and size of the radioactive material as it has a direct correlation on the dose received by the animal. After the exposure scenarios and exposure pathways were characterized, the development and implementation of the methods for estimating doses were compiled. For internal exposures, models from the ICRP Publication 60+ were employed to calculate the doses received through the pathways mentioned. While this method was not directly applicable, it was used due to the similarity between the structure of a human lung and that of a dog (N.P Singh et al. 1989, Thompson 1989).

For external exposures, calculations employed equations for determining the dose due to a radiation field. Because photons and electrons have different interaction mechanisms, different calculational methods were necessary to determine external exposure. The electron calculation employed relationships derived by Kocher and Eckerman (Kocher and Eckerman 1981):

$$DRF_E^T(Z', E_e) = \frac{1}{4}\frac{KE_e}{\rho_a}\frac{1}{r_0}R_e^a\Omega(Z', E_e) \qquad \text{Eq.1-1}$$

where

$$\Omega(Z', Ee) = \int_{\frac{Z'}{r_0}}^{\infty} \frac{1}{u} F_e^a(u, E_e) du \qquad \text{Eq.1-2}$$

Where the calculation for photons used equations developed by Kocher and Sjoreen (Kocher and Sjoreen 1983):

$$DRF_\gamma^a(z, E_\gamma) = \frac{1}{2} K E_\gamma (\frac{\mu_{en}}{\rho})_a \left\{E_1(\mu_a z) - \frac{A_a}{(B_a - 1)} exp\left[(B_a - 1)\mu_a z\right]\right\} \quad \text{Eq.1-3}$$

where

$$E_1(\mu_a z) = \int_z^{\infty} \frac{1}{r} exp\,(-\mu_a z\, r)\, dr \qquad \text{Eq.1-4}$$

While these methods have previously been used to calculate dose rate conversion factors for humans, these methods have never been used outside of that paradigm. The dose at a point in air above an area of uniform contamination is dependent on the radiation energy dependent physical properties of air. As a result, there is no significant difference in the suitability for use with USAR dogs than the change in height above the surface from 100 cm to 40 cm. The use of these methods to calculate values for USAR dogs opens a new realm of possibility for using these equations with other animals.

The next step evaluated uncertainties present in the calculations and dose estimates. These uncertainties can vary greatly not only with each animal but with the area of the reconstructed radiation field in which the animal will be working. Many possible errors were taken into consideration in the estimation of effects.

A final step in this research was to create a tool in the form of an Excel™ spreadsheet. This form allows a user to select radionuclides from the Federal Radiological

Monitoring and Assessment Center (FRMAC) list of radionuclides and then display their dose conversion factors (FRMAC 2015). The spreadsheet can be used to estimate both external and internal doses and display the results on separate sheets. The calculated results will be examined by the handler and the risk for possible radiation induced non-stochastic effects, such as loss of hair, reddening of the skin, vomiting, and mortality in the short-term. Stochastic effects such as genetic effects and cancer in the long-term will be evaluated. These risks estimates come from effects seen at different doses in studies done on dogs in the past (Prosser 1947, Raper 1947, Thompson 1989). The goal of this tool was to estimate both the external and committed effective dose equivalents received by the animals as a result of their exposures.

Justification of Research

This research was the first to produce photon and electron dose rate conversion factors for USAR dogs by applying methods previously used to calculate dose rate conversion factors for humans. In addition, it was the first to calculate inhalation dose rate conversion factors applicable for USAR dogs during working conditions. These goals were achieved by utilizing scaled FRMAC dose rate conversion factors for humans. The scaling parameters included air concentration at 40 cm, tidal volume, and lung masses.

Another result of this research was a spreadsheet, the first of its kind, that provides dose rate conversion factors for USAR dogs. This new tool allows first response dog handlers to create visual representations of data from dispersion models such as the QUIC Plume software. These visual representations such as, iso-dose curves and stay time curves, can be put on maps to indicate areas of concern or hazard. The results of the research estimate the likelihood of a USAR dog experiencing any radiation-induced effects as a result of their participation in a USAR mission. This research was the first to point out the gaps in research for animals under working conditions. These results will allow the first response teams and their dog-handlers to make informed decisions on USAR dogs use during radiological contamination events.

CHAPTER II

MANUSCRIPT 1: CALCULATION OF CANINE DOSE RATE CONVERSION FACTORS FOR PHOTONS AND ELECTRONS

Summary

Urban search and rescue (USAR) dogs are valuable members of their teams and play key roles in performing successful missions. A pair of dogs can do the work of dozens of people, the dogs are able to quickly sniff around collapsed structures and zip through constricted hallways with far greater accuracy than their plodding human counterparts. While in contaminated areas their human counterparts are afforded the benefit of personal protective equipment (PPE) to keep exposures to chemical, biological and radiological substances to a minimum. USAR dogs on the other hand do not. In an effort to allow USAR dogs to be utilized to their full potential, PPE is often not worn as it inhibits their ability to move in and around obstacles to use their strong senses of smell and hearing. In addition, these animals may snag or be snagged on debris or structures which may require rescue of the animal. In a collaborative effort between Texas A&M University's Department of Nuclear Engineering and the College of Veterinary Medicine, researchers are attempting to estimate the extent of the radiation doses received by these valuable team members during missions where radioactive contamination is present. Currently there are no dose rate conversion factors for USAR dogs, and those that are available are calculated at a height of one meter. To address this issue, a more suitable height of 40 cm was chosen and dose conversion factors were calculated for monoenergetic photon sources ranging

from 15 keV to 15 MeV and monoenergetic electron sources ranging from 10 keV to 10 MeV. The radioactivity is assumed to be uniformly distributed on the surface of the ground. Forty centimeters was chosen as the height of interest for the three breeds FEMA prefers as USAR dogs. These dose conversion factors will allow dose estimates to be made, allowing these animals to successfully do their jobs, while keeping their radiation doses as low as possible.

Introduction

USAR is considered a multi-hazard discipline, as it may be needed for a variety of emergencies and disasters, including terrorist activities and hazardous material releases. While working during one of these scenarios, the chance of entering a contaminated environment is high. As humans, we have the ability to utilize PPE to minimize our risk from exposure to potentially harmful substances that may be found during these types of scenarios. USAR dogs unfortunately do not have this luxury. Often the dogs perform what is called a “soft walk” where they must splay their paws in order to maintain maximum traction on the rubble pile. PPE makes the naturally agile dogs cumbersome and heavy making them less effective in maneuvering around the obstacles. PPE poses a safety concern as well, even the typical dog collar is avoided as it can add to the risk of injury when searching in tight or confined spaces (FEMA 2013). This means that utilizing PPE during a mission with potential radiological contamination is out of the question. Hence it is important to be able to estimate the doses received by these animals as they work in contaminated environments.

During missions where radioactive contamination is present, there are several pathways through which USAR dogs will be exposed. Internal exposure to resuspended material is a major pathway. While the concentration of material inhaled may be small, depending on the radionuclide and the emitted radiation, the doses received could be high. External exposure to the contamination will also be a major pathway, as the radiation field from the contamination will be constant, and depending on the amount of contamination present, may be high.

A radiation of particular importance is gamma rays. Research done by H.L Beck, D.C Kocher and A.L Sjoreen provided calculations of the dose rate conversion factors for exposure to photon sources both on the surface of the ground as well as at depths below the soil surface. The method used was based on a point-kernel integration method and assumes that the source concentration at any depth in soil was uniform over an infinite surface parallel to the plane formed by the ground surface (Kocher et al. 1985, 1983a,1983b, 1981a, 1980). These results are widely accepted and provide the basis for current dose conversion factors in emergency response guidelines.

Beta particles are also of concern because their range in air is several meters and are moderately penetrating. Beta radiation can result in burns to the skin if contact exists for prolonged periods of time. Burns resulting from beta particles on a sensitive area such as the pads of USAR dog's feet can be painful for the animal and hinder them from continuing their mission.

While there are published dose conversion factors for monoenergetic photons and electrons, as well as several available radionuclides, these values are calculated at a height of 1 m off the ground. This is not appropriate for calculating doses to USAR dogs. More suitable dose conversion factors are needed to accurately estimate the doses these animals receive during search missions in contaminated environments. Forty centimeters was decided to be an appropriate height when compared to the height of the FEMA preferred USAR dog breeds: Labrador retrievers, German Shepherds, and Belgian Malinois. With this new height value, dose rate conversion factors (DRCFs) for monoenergetic photons ranging from 15 keV to 15 MeV and monoenergetic electrons ranging from 10 keV to 10 MeV were generated. These new data are more appropriate for use with USAR animals than those previously available. Decay schemes were analyzed to determine the contribution to the doses resulting from photons and electrons. These values were used to calculate the DRCFs for the radionuclides of interest that are included in Appendix C of the Federal Radiological Monitoring and Assessment Center (FRMAC) manual; the guidelines for response to a radiological incident in the United States.

Methods and Materials

To calculate more accurate DRCFs for USAR dogs, Kocher and Sjoreen's point-kernel integration method was employed. This method assumes the source concentration is uniform over an infinite surface. In their work, the DRCFs at the height of the receptor, in air, for monoenergetic photon sources were calculated by integrating the gamma specific absorbed fraction, resulting in Eq 2-1:

$$DRCF_{\gamma}(z, E_{\gamma}) = \frac{1}{2} K E_{\gamma} \left(\frac{\mu_{en}}{\rho}\right)_a \{E_1(\mu_a z) - \frac{C_a}{(D_a - 1)} exp[(D_a - 1)\mu_a z]\} \qquad \text{Eq 2-1}$$

Where $DRCF_{\gamma}^{a}$ is the photon DRCF in air with units of Gy cm^2 $Bq^{-1}Y^{-1}$; K is a constant equal to 5.04 $x10^{-3}$ g-Gy s MeV^{-1} cm^{-2}; z represents the height of the receptor above ground (cm); E_{γ} is the energy of the photon in MeV; μ_a and $(\mu_{en}/\rho)_a$ are the mass energy absorption coefficient and linear attenuation coefficient for air at energy E_{γ} with units of cm^2 g^{-1} and cm^{-1} respectively ; A_a and B_a are the coefficients used in the Berger Form of the energy-absorption buildup factor in air, given here by Eq 2-2.

$$B_{en}^{a}(\mu_a r) = 1 + C_a \mu_a r \exp(D_a \mu_a r) \qquad \text{Eq 2-2}$$

While E_1 is the first-order exponential integral given by Eq. 2-3

$$E_1(\mu_a z) = \int_z^{\infty} \frac{1}{r} exp\,(-\mu_a r\,)\,dr \qquad \text{Eq 2-3}$$

It is important to note that the two terms in brackets in Eq 2-1, the ones involving the exponential integral and the buildup factor, give contributions from both unattenuatted and scattered photons with their respective contributions dependent on the photon energy and the areal density of the material between the source and the receptor (Berger 1968).

The values for the mass energy absorption were taken from the NIST X-STAR website, while the linear attenuation coefficient was calculated by taking the mass attenuation coefficient and multiplying by the density of air, also found on the NIST website (NIST 2012). The values for the coefficients used in the Berger form of the energy-absorption buildup factor in air were those of Shultis and Faw (1984). The solution for the exponential integral was found using Matlab 2015a. The data were then placed in an Excel spreadsheet used for calculations.

In addition to the calculation for monoenergetic photons, DRCFs were calculated for the radionuclides in the Federal Radiological Monitoring and Assessment Center (FRMAC) manual. These second calculations were carried out under the assumption that the spectrum of emitted photons consisted completely of discrete gamma rays and x rays. Using the method published by Kocher and Sjoreen (Kocher 1985), the equation employed in calculating the DRCFs for these radionuclides was:

$$DRCF_{\gamma} = \sum_{i} f_{i\gamma}\, DRCF_{\gamma}(E_i) \qquad \text{Eq. 2-4}$$

where $f_{i\gamma}$ is the intensity of the ith photon of energy $E_{i\gamma}$ in number of photons per decay with the summation including all the photons in the spectrum.

To calculate DRCFs for radionuclides, the energies and branching ratios of these photons must be known. The decay schemes for the FRMAC radionuclides of interest were obtained from the National Nuclear Data Center (BNL 2012). The DRCFS for these photons were found by interpolating on the data for monoenergetic photons using the interpolation function in Matlab 2014b. The respective dose rate conversion factors and the corresponding branching ratios were placed into Excel and summed using the sum function.

To successfully calculate the electron DRCFs for USAR dogs, the methods used by Kocher and Eckerman were employed (1980). In their research, the calculations were based on the assumption that the source region was effectively semi-infinite or infinite in extent with a uniform radionuclide concentration. This assumption is valid for electrons because of their relatively short range in air from radioactive decay (NAS 1964). The result is the electron dose equivalent rate per unit concentration for a given radionuclide.

The International Commission on Radiological Protection (ICRP) recommends that the dose to skin be calculated at a depth of 70 μm below the surface (ICRP 1977). Because the dermis extends considerably deeper than 70 μm, this dose is larger than the dose averaged over the entire thickness of the dermis. The dose rate conversion factors calculated in this research were calculated at 70 μm in order to have more conservative results.

Ideally, the DRCFs would be calculated by considering the transport of the electrons from the ground surface through the air to the height of the receptor and then through the tissue to a depth of 70 μm. Unfortunately, neither Monte Carlo nor empirical evidence of the specific absorbed fraction is available for the transport of electrons through two different materials. As a result, consideration of electron transport through air followed by transport in tissue is reduced to a consideration of transport through air alone. This is accomplished by replacing the assumed thickness of tissue by an equivalent thickness of air, which is added to the assumed height of the body surface above ground. This assumption produces more accurate results because most of the energy loss to the electrons occurs in the air between the ground surface and the skin surface (DOE 1985).

$$z' = z + 1.14(\frac{\rho_t}{\rho_a})x \quad \text{Eq. 2-5}$$

Eq. 2-5 shows the calculation of z’ where z is the height of the receptor; 1.14 approximates the ratio of mass stopping powers in tissue and air for any electron energy; ρ_t and ρ_a are the densities of tissue and air respectively; and x is the thickness that will be added to simulate tissue (Berger 1974). The resulting z’ was put into a spreadsheet to use for calculating the electron DRCFs.

Eq. 2-6 gives the dose rate factor at z' in air for monoenergetic electrons on the ground.

$$DRCF_{\varepsilon}(z', E) = \frac{1}{2} kER(E) \int_{s} \; \Phi_{a}\,(r, E)\; ds \qquad \text{Eq. 2-6}$$

where the factor of "½" accounts for the impenetrability of the body to electrons so that any point on the body surface is irradiated by electrons from only half of the source region: K is the constant 1.6x10^{-10} g-Gy MeV^{-1}; E is the electron energy in MeV; R(E) is the ratio of mass stopping powers in tissue and air; and Φ_a is the electron specific absorbed fraction in air.

Because an equation for electron specific absorbed fraction, similar to that for photons, is not available, a scaled electron point kernels developed by Berger must be used. These were obtained from the scaled point kernel in water and the energy-dependent scaling parameter α(E) as shown in Eq.2-7 (Berger 1974).

$$F^{a}(t, E) = \alpha(E) F^{w}(\alpha t, E) \qquad \text{Eq.2-7}$$

By substituting the scaled point kernel for the specific absorbed fraction in Eq.2-6, and using the relation

$$ds = 2\pi r\, dr \qquad \text{Eq.2-8}$$

the DRCF formula becomes

$$DRCF_{E}{}^{T}(Z', E_e) = \frac{1}{4} \frac{KE_e}{\rho_a} \frac{1}{r_0{}^{a}(E)} R(E) \Omega(Z', E_e) \qquad \text{Eq.2-9}$$

where

$$\Omega(Z', E_e) = \int_{\frac{Z'}{r_0{}^{a}}}^{\infty} \frac{1}{u} F_e{}^{a}(u, E_e)\; du \qquad \text{Eq.2-10}$$

The DRCFs were calculated for electrons with energies ranging from 10 keV to 10 MeV, with units of Sv cm^2 Bq^{-1} yr^{-1}.

To calculate the DRCFs for the radionuclides of interest, the decay spectra for each must be analyzed. A list of radionuclides in Appendix C of the FRMAC manual was compiled and a decay scheme was retrieved from the MIRD database at Brookhaven National Lab (BNL 2012).

The decay schemes were parsed with the goal of collecting the Auger and conversion electron branching ratios and beta energies for each radionuclide. Once these were collected, the energies were interpolated within the data to find the corresponding DRCFs. These data were used along with Eq. 2-11 to determine the contribution from conversion and Auger electrons with a discrete energy:

$$DRCF(x) = \sum_{\mathrm{i}} f_{ie}\, Dt(x, Eie) \qquad \text{Eq.2-11}$$

where f_{ie} is the intensity of the ith discrete electron in number per decay, and E_{ie} is the energy of the ith discrete electron in MeV.

The equation for calculating the DRCFs from beta decay required that the energy spectrum be normalized such that

$$\int_0^{EMax} Njb\,(E)\; dE \;=\; 1 \qquad \text{Eq. 2-12}$$

these normalized spectra were gathered from the BETADEC excel spreadsheet available on the RADAR Website (RADAR 2002, HP 2001). The values were interpolated through the monoenergetic energy data to find the corresponding DRCFs and used in Eq. 2-13 to calculate the contribution to the total dose rate factor from beta decay:

$$DRCF = \sum_i f_{i\beta} \int_0^{E\beta Max} N_{j\beta}(E)\;\; DRCF(x, E)\; dE \qquad \text{Eq.2-13}$$

The dose rate factors from discrete energy electrons and those from beta decay were then summed to obtain the total DRCFs from electrons:

$$DRCF(x) = \sum_{\mathrm{i}} f_{ie}\, DRCF(x, Eie) + \sum_{i} f_{i\beta} \int_0^{E\beta Max} N_{j\beta}(E)\ DRCF(x, E)\, dE \qquad \text{Eq. 2-14}$$

Results and Discussion

The calculated DRCFs for USAR dogs are presented in Table 2-1.

Table 2-1 Calculated photon DRCFs for USAR dogs

Energy (MeV)	DRCF (mrem cm^2 h^{-1} μCi^{-1})
$1.50\text{x}10^{-02}$	$1.07\text{x}10^{-04}$
$2.00\text{x}10^{-02}$	$8.03\ \text{x}10^{-05}$
$3.00\text{x}10^{-02}$	$5.13\ \text{x}10^{-05}$
$4.00\text{x}10^{-02}$	$4.32\ \text{x}10^{-05}$
$5.00\text{x}10^{-02}$	$4.26\ \text{x}10^{-05}$
$6.00\text{x}10^{-02}$	$4.50\ \text{x}10^{-05}$
$8.00\text{x}10^{-02}$	$5.34\ \text{x}10^{-05}$
$1.00\text{x}10^{-01}$	$6.43\ \text{x}10^{-05}$
$1.50\text{x}10^{-01}$	$9.23\ \text{x}10^{-05}$
$2.00\text{x}10^{-01}$	$1.21\ \text{x}10^{-04}$
$3.00\text{x}10^{-01}$	$1.76\ \text{x}10^{-04}$
$4.00\text{x}10^{-01}$	$2.27\ \text{x}10^{-04}$
$5.00\text{x}10^{-01}$	$2.74\ \text{x}10^{-04}$
$6.00\text{x}10^{-01}$	$3.19\ \text{x}10^{-04}$
$8.00\text{x}10^{-01}$	$4.00\ \text{x}10^{-04}$
$1.00\text{x}10^{+00}$	$4.75\ \text{x}10^{-04}$
$1.50\text{x}10^{+00}$	$6.36\ \text{x}10^{-04}$
$2.00\text{x}10^{+00}$	$7.74\ \text{x}10^{-04}$
$3.00\text{x}10^{+00}$	$1.02\ \text{x}10^{-03}$
$4.00\text{x}10^{+00}$	$1.23\ \text{x}10^{-03}$
$5.00\text{x}10^{+00}$	$1.44\ \text{x}10^{-03}$
$6.00\text{x}10^{+00}$	$1.64\ \text{x}10^{-03}$
$8.00\text{x}10^{+00}$	$2.04\ \text{x}10^{-03}$
$1.00\text{x}10^{+01}$	$2.43\ \text{x}10^{-03}$
$1.50\text{x}10^{+01}$	$5.31\ \text{x}10^{-03}$

These newly calculated DRCFs are higher than those calculated by Kocher et al. for the same energy as shown in Fig 2-1. It is expected that the calculated values should be higher than those calculated at 100 cm because of the reduced distance between the receptor and the source plane. This reduced distance between the source and receptor allows photons to successfully reach the receptor without the attenuation by air resulting in a higher fluence rate. An increased photon fluence rate produces more interactions in air producing more electrostatic charge per cubic meter resulting in a higher dose rate.

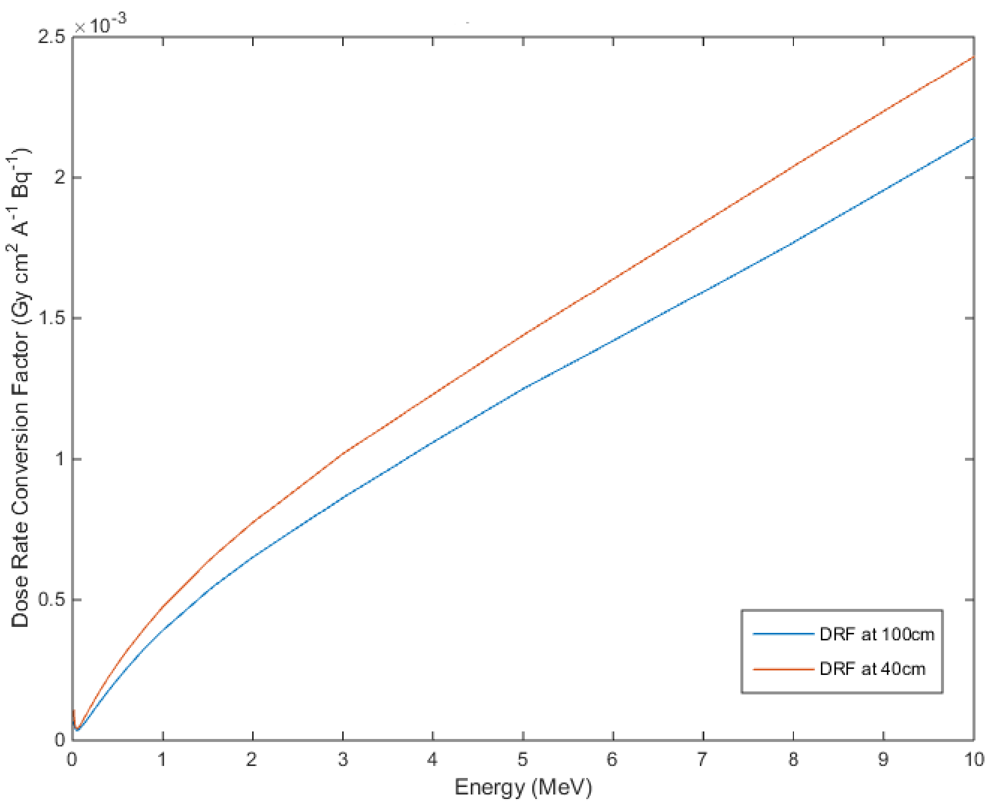

Figure 2-1. Comparison of photon DRCFs calculated at 40 cm and at 100 cm

Figure 2-1 shows that both sets of data share the same qualitative shape giving the author confidence in the validity of the calculated data. This figure also shows that at energies below 0.5 MeV the DRCFs only vary slightly from those calculated by Kocher and Sjoreen, while at energies greater than 1 MeV the differences become more pronounced. One possible explanation is that the different interaction mechanisms are the cause. At low energies, the photoelectric effect is the predominant interaction freeing more electrons in the air and causing a higher dose. As energy increases, Compton scattering becomes the dominant effect and electrons are scattered with low energy initially. But as the energy continues to increase the energy imparted to the scattered electron increases until the electrons are being scattered with energy high enough that they give up more energy through radiative losses than collisional. The air is not able to absorb the energy of the radiative loss resulting in the curve leveling off and giving us the shape of the curve.

The radionuclide specific conversion factors for photons of several radionuclides are included in Table 2-2.

Table 2-2. Radionuclide Photon DRCFs for several radionuclides of interest

Radionuclide	Energy (MeV)	Branching ratio (photons per disintegration)	DRCF (mrem cm^2 μCi^{-1} h^{-1})	Sum (mrem cm^2 μCi^{-1} h^{-1})
^{241}Am	0.0595	0.359	4.49x10^{-05}	1.75 x10^{-05}
	0.0263	0.0227	6.20x10^{-05}	
^{60}Co	1.3332	0.9985	5.82x10^{-04}	1.11x10^{-03}
	1.173	0.9998	5.31x10^{-04}	
^{137}Cs	0.0318	0.0199	4.98x10^{-05}	2.96x10^{-04}
	0.0322	0.0364	4.95x10^{-05}	

Table 2-2. Continued

	661.657	0.851	3.44×10^{-04}	
^{192}Ir	0.065122	0.0262	4.72×10^{-05}	4.42×10^{-04}
	0.066831	0.0444	4.79×10^{-05}	
	0.075749	0.0102	5.16×10^{-05}	
	0.29595	0.2871	1.74×10^{-04}	
	0.30845	0.297	1.80×10^{-04}	
	0.3165	0.8286	1.84×10^{-04}	
	0.46807	0.4784	2.59×10^{-04}	
	0.58858	0.04522	3.14×10^{-04}	
	0.60441	0.08216	3.21×10^{-04}	
	0.61246	0.0534	3.24×10^{-04}	

This method was carried out for the remaining radionuclides of interest. These results are included in Appendix A.

The results of the DRCF calculation for monoenergetic electrons are shown in Table 2-3 and plotted in Fig. 2-2.

Table 2-3. Calculated electron DRCFs for USAR dogs

Emitted Electron Energy (MeV)	Dose Rate Conversion Factor (mrem cm^2 μCi^{-1} h^{-1})
1.00×10^{-02}	$0.00 \times 10^{+00}$
1.50×10^{-02}	$0.00 \times 10^{+00}$
2.00×10^{-02}	$0.00 \times 10^{+00}$
3.00×10^{-02}	$0.00 \times 10^{+00}$
4.00×10^{-02}	$0.00 \times 10^{+00}$
5.00×10^{-02}	$0.00 \times 10^{+00}$
6.00×10^{-02}	$0.00 \times 10^{+00}$
8.00×10^{-02}	$0.00 \times 10^{+00}$
1.00×10^{-01}	$0.00 \times 10^{+00}$
1.50×10^{-01}	$0.00 \times 10^{+00}$

Table 2-3. Continued

2.00×10^{-01}	9.79×10^{-05}
3.00×10^{-01}	3.81×10^{-03}
4.00×10^{-01}	5.20×10^{-03}
5.00×10^{-01}	5.73×10^{-03}
6.00×10^{-01}	6.04×10^{-03}
8.00×10^{-01}	6.45×10^{-03}
$1.00 \times 10^{+00}$	6.75×10^{-03}
$1.50 \times 10^{+00}$	7.33×10^{-03}
$2.00 \times 10^{+00}$	7.81×10^{-03}
$3.00 \times 10^{+00}$	8.48×10^{-03}
$4.00 \times 10^{+00}$	9.13×10^{-03}
$5.00 \times 10^{+00}$	9.75×10^{-03}
$6.00 \times 10^{+00}$	1.04×10^{-02}
$8.00 \times 10^{+00}$	1.15×10^{-02}
$1.00 \times 10^{+01}$	1.25×10^{-02}

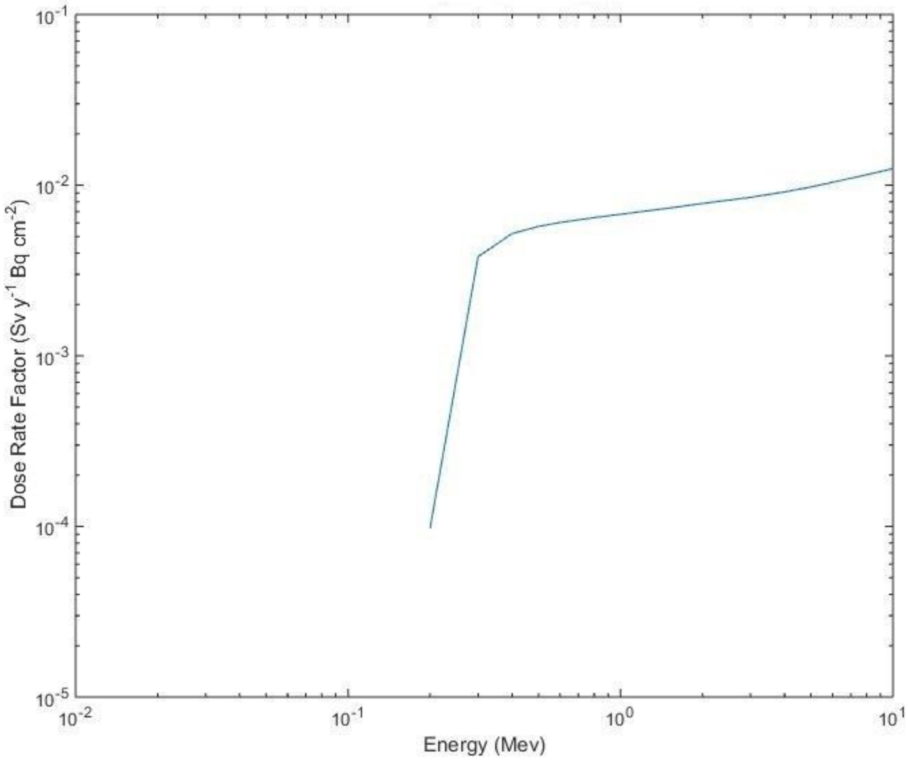

Figure 2-2. Calculated Dose Rate Conversion Factors for monoenergetic electrons for USAR dogs as a function of energy

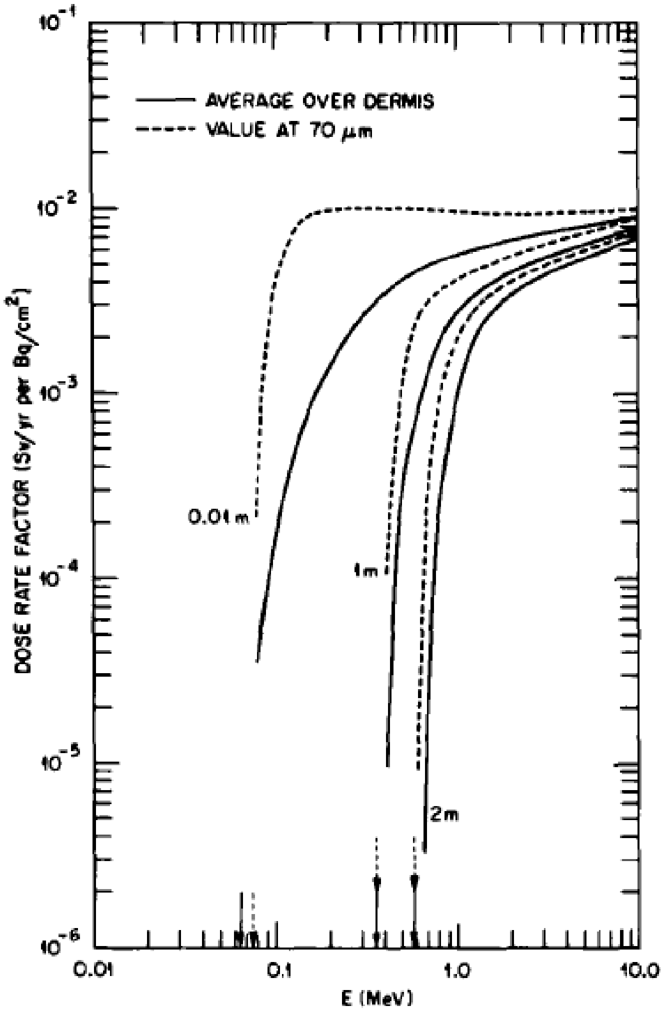

Figure 2-3. Calculated DRCFs for electrons at various heights (Kocher and Eckerman 1985)

When compared to values obtained by Kocher and Eckerman, the graph shows qualitative agreement. While there were calculations done for electrons down to 10 keV, the graph fails to show any below 200 keV, this is because the range of these particles in air is not sufficient enough to contribute to dose in the tissue.

Table 2-4 contains the DRCFs for a selected number of radionuclides of interest from Appendix C of the FRMAC manual.

Table 2-4 Electron Dose Rate Conversion Factors for selected radionuclides from the FRMAC manual

Radionuclide	Energy Range (MeV)			Dose Rate Conversion Factor (mrem cm^2 μCi^{-1} h^{-1})
^{140}Ba	0.00E+00	-	1.01E+00	8.73E-02
^{144}Ce	0.00E+00	-	3.15E-01	1.63E-02
^{60}Co	0.00E+00	-	1.49E+00	1.05E-01

One of the reasons for differences in the calculation process for gamma and beta emitting radionuclides is a difference in method for calculating the doses due to beta decay. Kocher and Eckerman used the energy distribution function for electrons obtained from the Fermi theory, while the calculations done in this research utilized average energies from energy bins to best estimate the beta spectrum. This method is simpler than that used by Kocher and Eckerman, but should yield comparable values that vary only slightly from those calculated via the Kocher-Eckerman method.

Conclusions

USAR dogs are gifted creatures with abilities that make them elite team members on many first response teams. Their keen sense of smell and natural agility allows them to surpass human abilities during USAR missions. While dogs play a very important role in the success of USAR operations, their lack of protective equipment leaves them susceptible to hazardous material they may encounter during their missions. This inability to wear PPE is a major concern during missions in which radiological contamination is present. Current DRCFs for use by USAR workers, are located in appendix C of the FRMAC manual but are unsuitable for use with USAR dogs because they are calculated at a much higher height. As a result, this research provides DRCFs at a height better suited for USAR dogs as a way to better protect these crucial assets.

This research presents the calculation of DRCFs for USAR dogs subject to photon and electron emitting radiological contamination on the ground surface. The calculations utilized methods introduced by Kocher and Sjoreen and Kocher and Eckerman which assumed an infinite uniformly-distributed, plane source. As expected with the photon DRCFs, the values calculated at 40 cm were higher than the values calculated at 100 cm and showed the same qualitative shape when plotted as a function of energy. The electron DRCFs showed the same qualitative shape as the data produced by Kocher and Sjoreen and showed agreement when compared to their plot of DRCFs as a function of height. From these results, DRCF's for the FRMAC radionuclides of interest were computed using their respective decay schemes. The results of this research can be used to create a tool for calculating doses to USAR dogs to better ensure their safety in radiologically contaminated environments.

CHAPTER III

MANUSCRIPT 2: CALCULATION OF CANINE INHALATION DOSE RATE CONVERSION FACTORS

Summary

Urban search and rescue (USAR) dogs are great assets to any emergency response team. Their keen sense of smell and agility allow them to perform duties that would otherwise be impossible for their human counterparts. During missions where radioactive contamination is present, USAR dogs are going to be especially susceptible to exposure because of their lack of protective equipment. As these animals do their duties, they could incur a large dose due to inhalation of material in the air. Current dose rate factors for inhalation of resuspended materials are available in Appendix C of the Federal Radiological Monitoring and Assessment Center (FRMAC) manual for emergency responders. These values are not suitable for use with USAR animals because of the height at which they are calculated, as a result there is no way to estimate the doses that will be received by these valuable team members. This research attempts to calculate a correction factor for the values in the FRMAC manual based on resuspension research done by Anspaugh et al. to better suit the material concentration present in the breathing zone of the search and rescue dogs.

Introduction

Urban search and rescue (USAR) dogs are valuable members of search and rescue teams around the country. From wildfires to hurricanes and tornadoes to terrorist events, these animals help their teams in a variety of scenarios, and play roles crucial to mission success. Their agility in unstable environments makes them perfect to maneuver around rubble piles and into places that their human counterparts cannot. Also, their keen sense of smell allows them to detect and distinguish the unique scent of a human buried beneath rubble and debris all while working with countless other humans (Buzzfeed 2014).

During their mission activities, USAR dogs are not afforded any personal protective equipment (PPE) to protect themselves. The reasons reflect both safety and performance concerns. Currently, the only PPE available is a set of booties to be worn on rubble piles and often times they are not used as they affect the ability of the animals to splay their feet resulting in a loss of traction on the piles. Further, PPE has the potential of getting caught on debris and put the animals in danger. As a result, dogs are not allowed to even wear collars while on a pile (FEMA 2009). This lack of protective measures means that during missions the animal will be directly exposed to any hazardous materials they come across, possibly resulting in a negative impact on performance and health.

The FRMAC Assessment Manual is used to assess and define the technical methods for performing radiological assessment for humans (FRMAC 2015). It contains procedures for assessing doses to the public and response personnel. It describes techniques for performing ingestion pathway analysis as well as containing a wealth of information in the many tables and appendices located throughout. Of particular importance in this research is Appendix C, which contains tables of radiological data, shielding/protection factors, dose parameters and derived response limits for the early phase on out to 50 years. Table 4-3a of the Assessment Manual gives the avoidable committed dose, i.e., the dose that can be avoided by taking protective actions, during the post-plume passage early phase of an incident. This is most important for first responders because while they will not be arriving during the passage of the plume, they will arrive during the early phase. It is this parameter that will be the focus of this research. To calculate dose parameters for canine USAR workers. These calculations will involve using information relating to the atmospheric transport of material and scaling biological parameters to produce a result that estimates dose rates in the canine respiratory zone due to resuspended material during USAR missions.

Methods and Materials

Early research showed that despite the large size variations in mammals all around the world, their major organs are remarkably similar in morphology and function. Using the assumption that the lungs of large and small mammals are physical analogues of each other, Stahl et al. used compiled data and statistically fitted power laws to predict various respiratory parameters based on animal mass (1966). Parameters for the power function were derived from data collected from physiological journals, handbooks and checked for consistency and validity (Stahl 1966). There are three breeds of dogs most preferred by FEMA to become search and rescue dogs, Labrador Retrievers, German Shepherds and the Belgian Malinois. Information was gathered on their average weight for use in calculation of respiratory minute volume and lung weight using the predictive power functions. Human respiratory information was collected from ICRP Publication 89, the updated anatomical and physiological data for radiation protection (ICRP 2002). It should be noted that minute volume is not a parameter available in ICRP 89. However using unit analysis ventilation rate from ICRP Publication 89 was converted to minute volume.

For calculation of the canine respiratory parameters, the power function followed the form (Stahl 1966):

$$X = aM^b \qquad \text{Eq.3-1}$$

where X is the variable to be calculated, M is the mass of the animal in kg, a is the value of the variable for a 1 kg "standard animal" and b is the slope on a log-log graph. Both of these parameters were provided through the Stahl reference. Data were collected for all three breeds and both genders of dog, but since it will not be known what breed or gender of dog will be responding to an incident at any time, the decision was made to average the collected data. Table 3-1 shows the average weights of the dog breeds.

Table 3-1. Average weights of dog breeds used in urban search and rescue

Breed of Dog	Avg weight range of male (kg)	Avg. weight range of female (kg)
Belgian Malinois	29-34	25-30
German Shepherd	30-40	22-32
Labrador Retriever	29-36	25-32
Average weight (kg)	30.33	

Figure 3-1 contains a plot of the respiratory data collected for both canines and humans

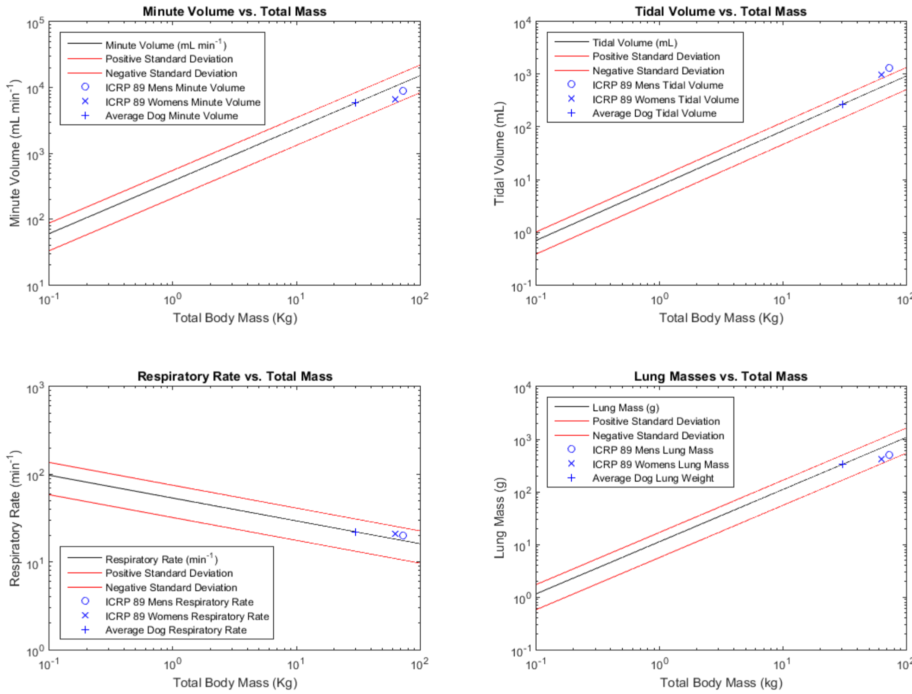

Figure 3-1. Respiratory data collected for use in creating scaling factors to calculate dose rate conversion factors

The concentration of material at canine respiratory height was calculated using an equation derived from resuspension research carried out by Anspaugh et al. Eq.3-2 gives the relationship between height above the ground, Z, and concentration of resuspended material at that height X(Z) (Anspaugh 1974):

$$X(Z) = \left(\frac{Z}{X(1m)}\right)^{-p} \quad ; \qquad \text{Eq. 3-2}$$

where X(1m) represents the concentration of material at 1 meter, while p is the power of Z. The p value has been measured from -0.35 to -0.25 (Anspaugh 1975). Figure 3-2 shows the two concentration gradients together, with an emphasis at the 40 cm height.

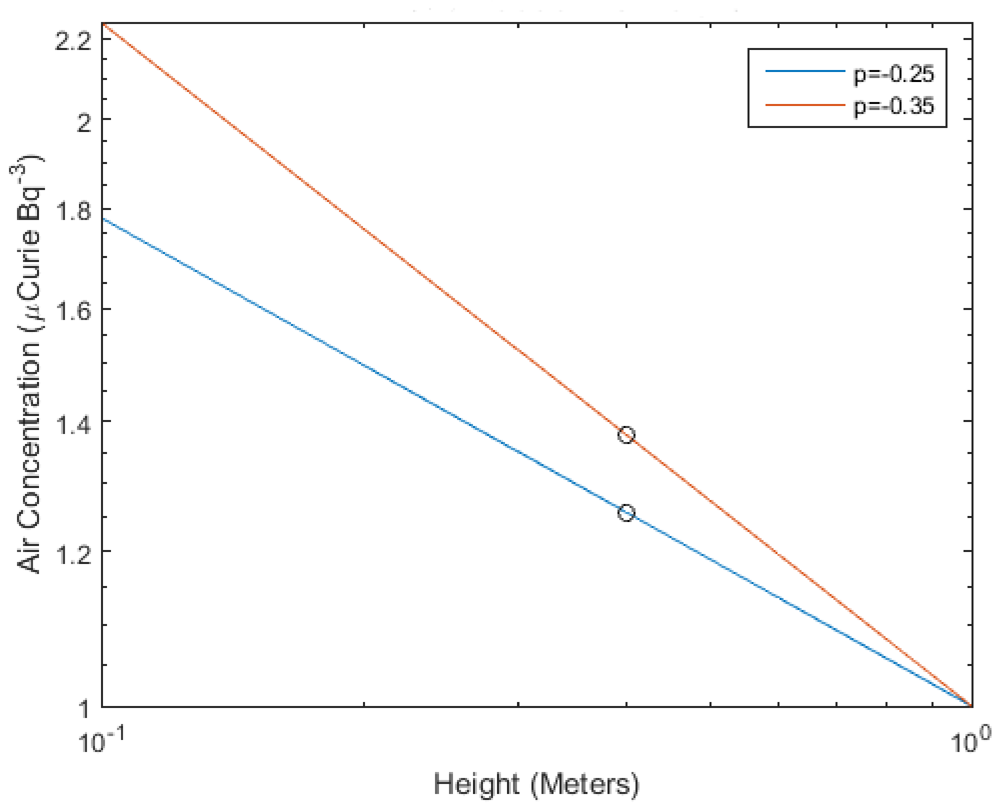

Figure 3-2. The percent change in air concentration as a function of height compared to the concentration at 1 meter

In an effort to yield a conservative answer, p was chosen to be -0.35 because it reported a higher concentration of material in the canine respiratory volume.

Ratios between the human values and the canine values were obtained for use in scaling the human DRCFs in the FRMAC manual. Those ratios are shown in Table 3-2.

Table 3-2. Ratios of respiratory values used for calculation of canine DRCFs

Value	Human	Canine	Ratio
Lung weight (grams)	460.0	337.18	0.733

Table 3-2. Continued

Tidal Volume (mL)	1145.0	267.30	0.233
Respiratory Rate (min^{-1})	20.5	22.03	1.07
Minute Volume (mL min^{-1})	7750.0	5808.7	0.749

Canine dose rate conversion factors were then computed using a scaling factor derived from the calculated ratios and air concentration data.

Results and Discussions

The canine dose rate conversion factors are provided in Table 3-3.

Table 3-3 Calculated Inhalation DRCFs for USAR dogs

Radionuclide	Dose Rate Conversion Factor mrem cm^2 h^{-1} μCi^{-1}	Radionuclide	Dose Rate Conversion Factor mrem cm^2 h^{-1} μCi^{-1}
^{241}Am	$4.14x10^{00}$	^{237}Np	$1.42x10^{-01}$
^{140}Ba	$2.81x10^{-04}$	^{239}Np	$2.66x10^{-05}$
^{141}Ce	$1.48x10^{-04}$	^{147}Pm	$2.96x10^{-04}$
^{144}Ce	$2.22x10^{-03}$	^{238}Pu	$4.59x10^{00}$
^{252}Cf	$1.63x10^{00}$	^{239}Pu	$5.03x10^{00}$
^{242}Cm	$2.51x10^{-01}$	^{241}Pu	$9.76x10^{-02}$
^{244}Cm	$2.37x10^{00}$	^{226}Ra	$7.99x10^{-01}$
^{60}Co	$1.30x10^{-03}$	^{103}Ru	$1.15x10^{-04}$

Table 3-3 Continued

^{134}Cs	$8.58x10^{-04}$	^{106}Ru	$2.66\ x10^{-03}$
^{136}Cs	$1.07\ x10^{-04}$	^{127}Sb	$5.47\ x10^{-05}$
^{137}Cs	$1.63\ x10^{-03}$	^{129}Sb	$5.03\ x10^{-07}$
^{153}Gd	$1.01\ x10^{-04}$	^{75}Se	$5.47\ x10^{-05}$
^{129}I	$1.48\ x10^{-03}$	^{89}Sr	$3.11\ x10^{-04}$
^{131}I	$2.66\ x10^{-04}$	^{90}Sr	$6.51\ x10^{-03}$
^{132}I	$1.92\ x10^{-07}$	^{91}Sr	$3.55\ x10^{-06}$
^{133}I	$1.92\ x10^{-05}$	^{129m}Te	$3.11\ x10^{-04}$
^{134}I	$3.55\ x10^{-08}$	^{131m}Te	$4.14\ x10^{-05}$
^{135}I	$1.48\ x10^{-06}$	^{132}Te	$5.47\ x10^{-05}$
^{192}Ir	$2.81\ x10^{-04}$	^{170}Tm	$3.70\ x10^{-04}$
^{140}La	$2.51\ x10^{-05}$	^{91}Y	$3.55\ x10^{-04}$
^{99}Mo	$2.81\ x10^{-05}$	^{169}Yb	$1.15\ x10^{-04}$
^{95}Nb	$7.10\ x10^{-05}$	^{95}Zr	$3.85\ x10^{-04}$

The canine DRCFs were calculated using a scaling factor derived by multiplying the human DRCF by the percent increase in the air concentration. The calculation was done under the assumption that an increased material concentration in the canine breathing volume would result in an increased dose whose ratio when compared to that of a human is equivalent to the percent increase in material concentration. If all other respiratory parameters were the same, this consideration would be the only value of importance for the scaling factor. However, this is not so and we must consider the other respiratory variables.

The physiological properties of the canine and human are so much alike that this allows the direct comparison of the respiratory parameters to be used in the scaling factor (Lung Task Group 1966, Thomas N.D., Thompson 1989, Singh et al. 1989). An analogy that can be drawn is that of two pumps that work in the same manner, but are of differing sizes. Because the mechanisms that drive the pumps are similar, it is possible to directly compare the two. In this case the minute volumes, the volumes of air taken in per minute, are being compared. Since the minute volume for the canine is smaller than that of the human, less air is inhaled leading to a reduction of the scaling factor.

Absorbed dose is calculated as energy deposited per unit mass. Because the mass of the lung for the canine is less than that of the human, there is less mass in which to deposit energy into, resulting in greater absorbed dose. This ratio of lung masses leads to an increase in the scaling factor.

There are many sources of uncertainty associated with these results stemming from uncertainty in experimentally derived variables and values and uncertainty in methods. For instance, the *a* value used in Eq.1, has a reported standard error of the mean of 40%. Additionally, the human data collected was for a person during light exercise conditions while the conditions under which the dog data were calculated is unknown. There are also uncertainties in the biodosimetric models from which the human DRCFs factors were calculated. These reasons make quantifying the uncertainty difficult, but work is being done on methods to analyze the uncertainty in internal dosimetric calculations (Bouville

2009, Napier 2009, Puncher 2008). These methods would allow realistic uncertainties to be calculated, allowing for increased accuracy in computing dose rates to USAR animals. With increased knowledge of the dose rates in which the dogs are working, USAR handlers can make better decisions to prevent stochastic and deterministic effects to their animals.

Conclusions

Search and Rescue canines are treasured members of the search and rescue teams that they serve. They have unique talents that are not easily made up for by other instruments or workers. Because of a lack of personal protective equipment USAR dogs are directly in contact with potentially hazardous materials. In the case of radioactive contamination, first responders turn to the FRMAC manual to get information on methods for protection of the public and workers. It is here that they use the values in Table 4-3a in Appendix C of the FRMAC Assessment Manual to determine the avoidable committed dose to search and rescue personnel. The assumptions under which these values have been calculated they are not valid for canines. Research has been carried out to determine DRCFs for canines similar to those for humans. Using respiratory data for canines and humans and atmospheric concentration data evaluated at the canine respiratory height, a scaling factor was calculated. Since the canine and human respiratory systems are very similar in physiology, the human dose rate conversion factors were used and modified with the scaling factor to produce dose rate conversion factors valid for canines exposed to radioactive contamination.

CHAPTER IV

MANUSCRIPT 3: CREATION OF A DOSIMETRY TOOL UTILIZING THE CALCULATED CANINE DOSE RATE CONVERSION FACTORS

Summary

Urban Search and Rescue (USAR) dogs require a large commitment from their handlers, to keep them trained and in good health throughout their careers. Additionally, the majority of these animals are not just coworkers, but beloved family pets. It is no wonder that the safety of these animals during a mission is of such high priority to their handlers. In a collaborative effort between Texas A&M University's Department of Nuclear Engineering and the College of Veterinary Medicine and Biomedical Sciences, a tool was developed utilizing DRCFs calculated specifically for USAR canines that will assist in keeping their radiation doses as low as possible during missions involving radiological contamination. This tool enables canine handlers to select sources from the Federal Radiological Monitoring and Assessment Center (FRMAC) radionuclides of interest list and display external and resuspension dose rates based on the areal concentration of material. Visual representations such as iso-dose curves can be derived from these data, allowing canine handlers to plan their response tactics accordingly. The tool was created in Excel™, allowing for easy deployability in the field on a variety of platforms.

Introduction

Not every dog is suited to become a USAR dog. The National Disaster Search Dog Foundation (SDF), a kennel that trains USAR dogs in California sought out thousands of dogs in 2012, actively recruited 200 and of those only 40 went on to graduate training (Buzzfeed 2014). The work of a search dog is stressful and incredibly difficult, but a well-trained USAR dog is a sight to behold. They can maneuver around the most difficult terrain with the grace of a mountain goat all while looking for trapped or hidden human beings (Bryant 2016). A USAR canine is able to distinguish between the scents of hundreds of rescuers at a site and that of a human trapped under debris (Buzzfeed 2014). These unique skills make USAR canines such special members of USAR teams around the world. While dogs naturally have these skills, it takes years of intense training to harness and focus them to accomplish a mission. Working USAR dogs typically complete more than 600 hrs of training before qualifying for emergency work (Layton 2005). This training can be quite expensive, sources estimate the cost to fully train each dog to be around $15,000-$20,000 (Flood 2014).

Not only is there a monetary investment, a strong emotional investment is also involved. On top of the spending time together training to become mission ready, USAR handlers are frequently also the owners of their dogs. This bond has been studied and is shown to be similar to the deep connection between young children and their parents (Franklin 2009). Considering the hazards associated with USAR missions these handlers make it a priority that their dogs stay safe at all times during their missions.

Safety for USAR dogs is difficult to achieve. Because of their activity around rubble piles and tight spaces USAR dogs are not permitted to wear collars due to of the risk of being caught and choked. Personal protective equipment is also an issue, while booties are available to protect the feet of USAR dogs. But, booties are often not used because they do not allow the dog to splay their toes for traction (FEMA 2013). This lack of protective equipment poses a significant risk during missions involving toxic substances.

Currently there is no literature describing research that has been done with the aim to reduce risk to USAR dogs in the field. There is, however, a plethora of information available for humans.

For scenarios involving radioactive material, the Federal Radiological Monitoring and Assessment Center (FRMAC) Dose Assessment manual is the gold standard. The tables and information within are used to estimate doses to the public and emergency responders from the beginning of the incident to as long as 50 years later. Unfortunately, there are no data in this manual pertaining to the protection of search and rescue dogs. This research aims to provide a solution to this problem by creating a tool for calculating dose rates and other emergency response parameters for USAR dogs during missions involving radioactive material.

Methods and Materials

During USAR missions it is not uncommon to find a computer in addition to a bevy of other technological tools and applications. MS Office, which includes Excel is typically installed on these systems. Excel is a spreadsheet software initially developed by Microsoft for the Windows operating system in 1985. Since then it has been released on Mac OS X, Android and iOS operating systems and is now the industry standard spreadsheet software. To capitalize on the familiarity with Excel and its availability on a wide variety of platforms, the choice was made to create the tool in Excel. This choice also avoided the issue of having to install special software that may be expensive and difficult to use or issues with operating system compatibility. The spreadsheet utilizes many features of the spreadsheet program such as drop-down menus for selecting from the radionuclides of interest, conditional color formatting for visuals and the mathematical capabilities within the cells to complete the calculations.

The FidoFRMAC tool is made up of several sheets within the file. These additional sheets are labeled 'Deposition', 'External', 'Internal' and 'Total'. The initial sheet, labeled FidoFRMAC, is where the user interfaces with the spreadsheet. It contains two distinct sections, one for calculating USAR parameters that may be important during a mission, and another that displays the dosimetric information for the radionuclides.

USAR Parameters

The tool has several sections used to calculate important parameters for emergency responders and canines that may be involved in radiological incidents. Staytime represents the amount of time that a worker may stay in a given location and not exceed their established dose limit based on external dose measurements made in the working location. Stay time is calculated in FidoFRMAC using Eq 2.1-2 from the FRMAC manual (FRMAC

2015). For USAR canines working times vary, but 20 minutes is a typical standard (MacPherson 2014):

$$Stay\ Time = \frac{Dose\ Limit}{Dose\ Rate} \quad \text{Eq. 4-1}$$

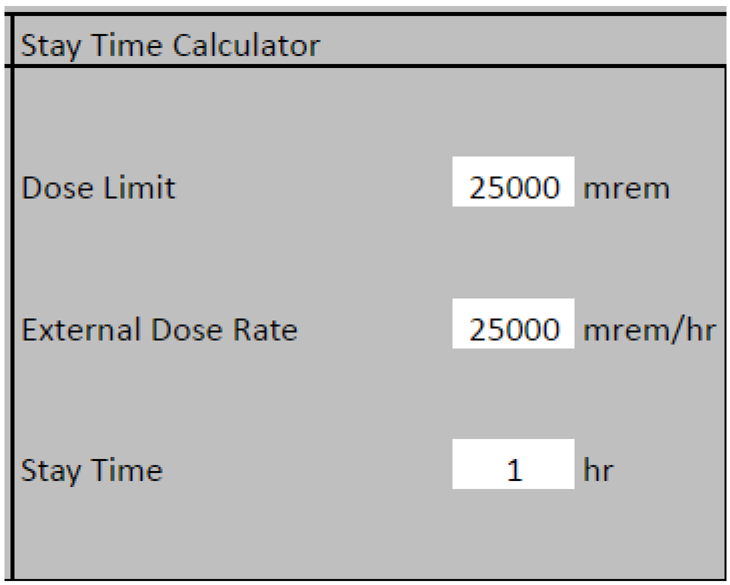

Figure 4-1 A view of the Stay Time Calculator in FidoFRMAC

where Dose Limit is the dose that a worker is allowed to receive for a shift in mrem, and Dose Rate is the measured dose rate in mrem h^{-1}. Figure 4-1 features the stay time calculator as found in FidoFRMAC

A section of the tool is dedicated to calculating turnback limits as well, this section is used to calculate the turnback limit according to FRMAC Assessment Manual Equation 2.1-1 (FRMAC 2015):

$$TBL = \frac{Dose\ Limit}{Stay\ Time} \quad \text{Eq.4-2}$$

Figure 4-2 features the turnback limit calculator as found in FidoFRMAC

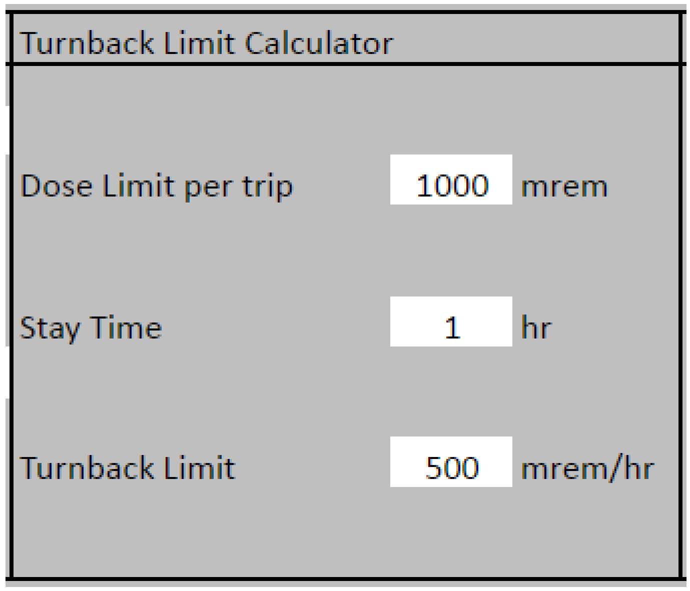

Figure 4-2 A view of the Turnback Limit Calculator in FidoFRMAC

In addition, there is a section for inputting mission information. This section allows the canine handler with the proper information to plan out the number of missions and mission duration and allows the user to plan for an extended mission lasting several days. Information such as Total Dose Limit can be entered as well as missions per day and length of time per mission to establish the dose limit per trip in mrem. This information can be placed into the other calculators to obtain an initial understanding of the radiological scenario. A unit converter from minutes to hours is also included, this takes the pressure off of the first responder to do any calculation themselves.

Dosimetry Parameters

The tool features the ability to select one or multiple radionuclides. The selected radionuclides have their DRCFs, the dose rate produced from 1 microcurie per meter squared, for both external exposure and internal intakes due to resuspension displayed upon selection.

The radionuclide selection is based on Table 4-3a in the FRMAC Assessment Manual. The tool will display DRCFs for external, internal and total doses. These DRCFs were previously calculated using equations derived from research done by David Kocher (Kocher 1981, 1983, 1985). Instead of having the DRCFs evaluated at one meter as done for humans, the canine DRCFs are evaluated at a more appropriate height of 40 centimeters (Trevino). Additionally, radiological data, such as specific activity and half-life, are available after a radionuclide is selected from the list. The dosimetry section is provided in Figure 4-3.

Extra sheets are used to compute the dose rates from deposition files created by atmospheric dispersion simulations such as QUIC Plume and HOTSPOT. The minimum and maximum dose rates calculated using these sheets are displayed alongside the other dosimetric information.

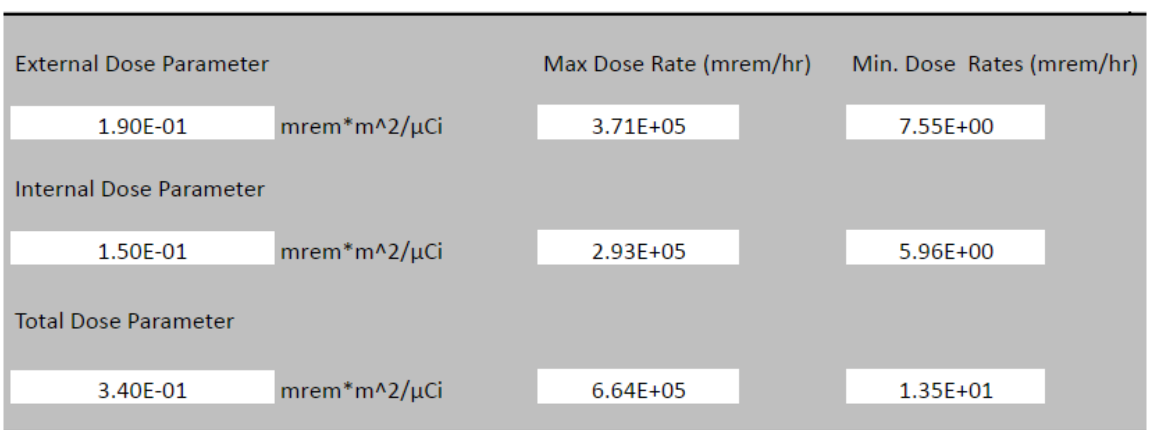

Figure 4-3 A view of the dosimetry panel in FidoFRMAC

Results and Discussion

A major concern to emergency responders are Radiological Dispersal Devices. These "dirty bombs" pose the greatest threat because of their relatively simple designs that require no more than an explosive and some amount of radioactive material. This can be demonstrated by the crude pressure cooker bombs constructed by the Boston Marathon Bombers (Boston Globe 2014). While there was no radioactive material involved with these weapons the chaos that ensued would only be intensified if radioactive material had been present. Like other types of explosives, the mechanics of the detonation are complex and thus deposition of material depends on several factors. These factors include geometry and size of the explosive, and the chemical form of the radionuclide. Research conducted by Fred Harper and Stephen Musolino at Sandia National Laboratory, shows how these variables combine to produce a spectrum of possibilities (Harper et al. 2007).

One way for first responders to get an idea of the scenario is to utilize atmospheric dispersion models to approximate the deposition. These models utilize methods such as the Gaussian Plume Model and Lagrangian Transport Model along with meteorological and radiological data to produce an estimate of the resulting deposition (Homann 2013, Brown 2012). This deposition can be used with DRCFs to calculate the resulting dose rates from a given deposition.

$$Dose\ Rate = Dose\ Rate\ Conversion\ Factor\ x\ Deposition \qquad \text{Eq. 4-3}$$

where the dose rate conversion factor is in units of mrem h^{-1} m^2 μCi^{-1} and deposition is given in units of $\mu Ci\ m^{-2}$.

Utilizing this concept, FidoFRMAC allows users to input estimated deposition data from these models and use the selected DRCFs to compute grids of the resulting dose rates. To enter deposition data, the user simply copies the deposition file and pastes it into the sheet labeled ‘Deposition’. For the calculated dose rates to be in the proper units, the deposition should be in units of $\mu Ci\ m^{-2}$

The color conditional formatting features of Excel® allows the visualization of the data including how the dose rates vary over the contaminated space. From these images first responders and dog handlers can better plan their mission strategies to better protect their canines.

The FRMAC manual has three DRCFs for use by humans, external, internal, and total. FidoFRMAC provides three dose rate conversion factors for USAR dogs as well. To successfully calculate the dose rates for each, a separate sheet of the spreadsheet is used. These can be seen at the bottom of the screen and allows the handlers to see how the external, internal and total dose rate are varying over the space. This is shown in Figure 4-4.

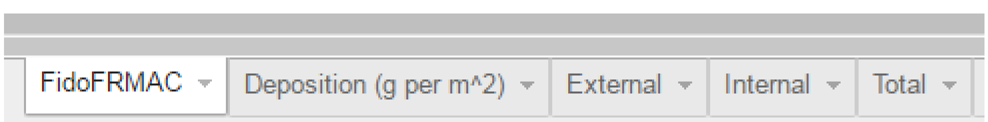

Figure 4-4 The sheet structure of FidoFRMAC that allows handlers to see multiple dose rate displays

It should be noted that this tool cannot be used to compute exact dose estimates. Because of the possible variation in material deposition throughout a space, the dose rate could change wildly depending on where they are at any given time. To make the matter even more difficult, as USAR dogs search for victims trapped within the rubble, “hot spots” may be present and the dog will be moving quickly from place to place. This lack of a definite time or dose rate in a particular region makes it difficult to precisely calculate dose to the animal.

Conclusions

It takes a lot of hard work and dedication to become a USAR dog. There are countless hours spent training together with their handlers to successfully maneuver around rubble piles and handle the stressful situations they may encounter. This training results in a bond between handler and dog that has been likened to that of a parent and child, but comes at a cost. Estimates of the costs to completely train a USAR dog range from $15,000 to $20,000. This emotional bond is made even stronger by the fact that handlers are often the owners of their animals. With so much invested in these animals, it is no wonder that there is a concerted effort to keep them safe.

The FidoFRMAC tool was created for use by USAR dog handlers to provide dose rate estimates for their animals in radiologically contaminated environments. The tool utilizes previously calculated DRCFs and allows for an input from atmospheric dispersion tools to compute dose rates at points within the contaminated area. In addition to the dosimetry information, there are calculators for other important USAR parameters such as the turn back limit and stay time. There is also a section to plan for extended USAR missions.

While a disaster involving radiological material is never wanted, it is hopeful that if such should occur, the handlers will have the ability better protect their animals with information procured using this tool.

CHAPTER VI CONCLUSIONS

Case Study

The following is meant to provide an example on how the information and tools developed as part of this dissertation could be employed during an emergency that involves the explosive dispersion of radioactive material.

Scenario

As an example, a simulated RDD is detonated in downtown Sierra, Texas. The explosion results in the total collapse of 1 building as well as severely damaging nearby structures. In addition a radioactive plume is produced that disperses over 36 city blocks. Early, during the emergency, Hazardous Material Specialists with the fire department have identified high levels of cesium-137 (^{137}Cs) in and around the damaged structures. Emergency response engineers determine the unstable structures and debris are deemed safe to enter. Urban Search and Rescue (USAR) dogs are called in to help locate survivors.

Dose Modeling

During the initial stages of the event computer models developed by the National Atmospheric Release Advisory Center (NARAC) would be used to illustrate potential contamination. Fig 5-1 shows an example of a NARAC plume model. USAR health and safety specialists along with the USAR dog handlers would use such information along with FidoFRMAC to assess the risk to their dogs. With the knowledge that the radioactive agent is ^{137}Cs, they would select the proper DRCFs and develop their own maps of dose rates for canine inhalation and exposure.

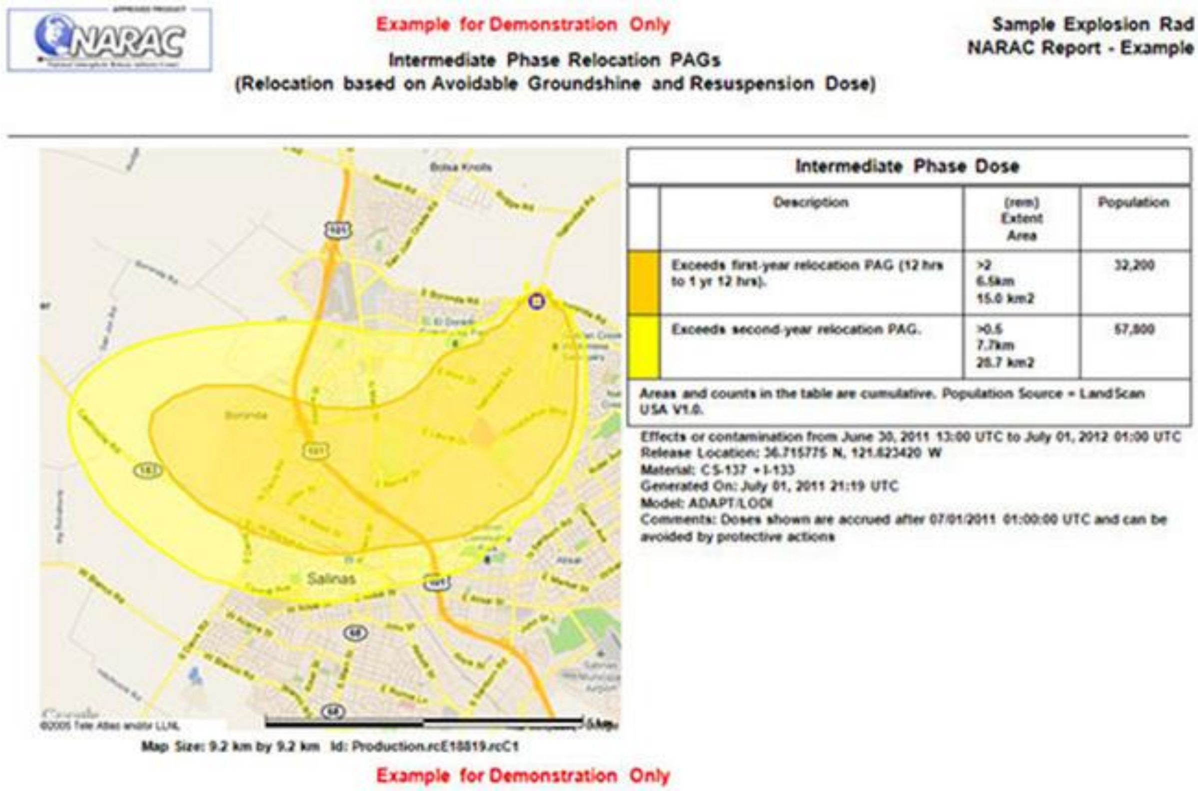

Figure 5-1 Example of a NARAC product for a radiological dispersal device

After inputting the NARAC model for deposition into FidoFRMAC the results are displayed in Fig 5-2. Fig 5-3 is an expanded area to more clearly show the estimated dose rate data.

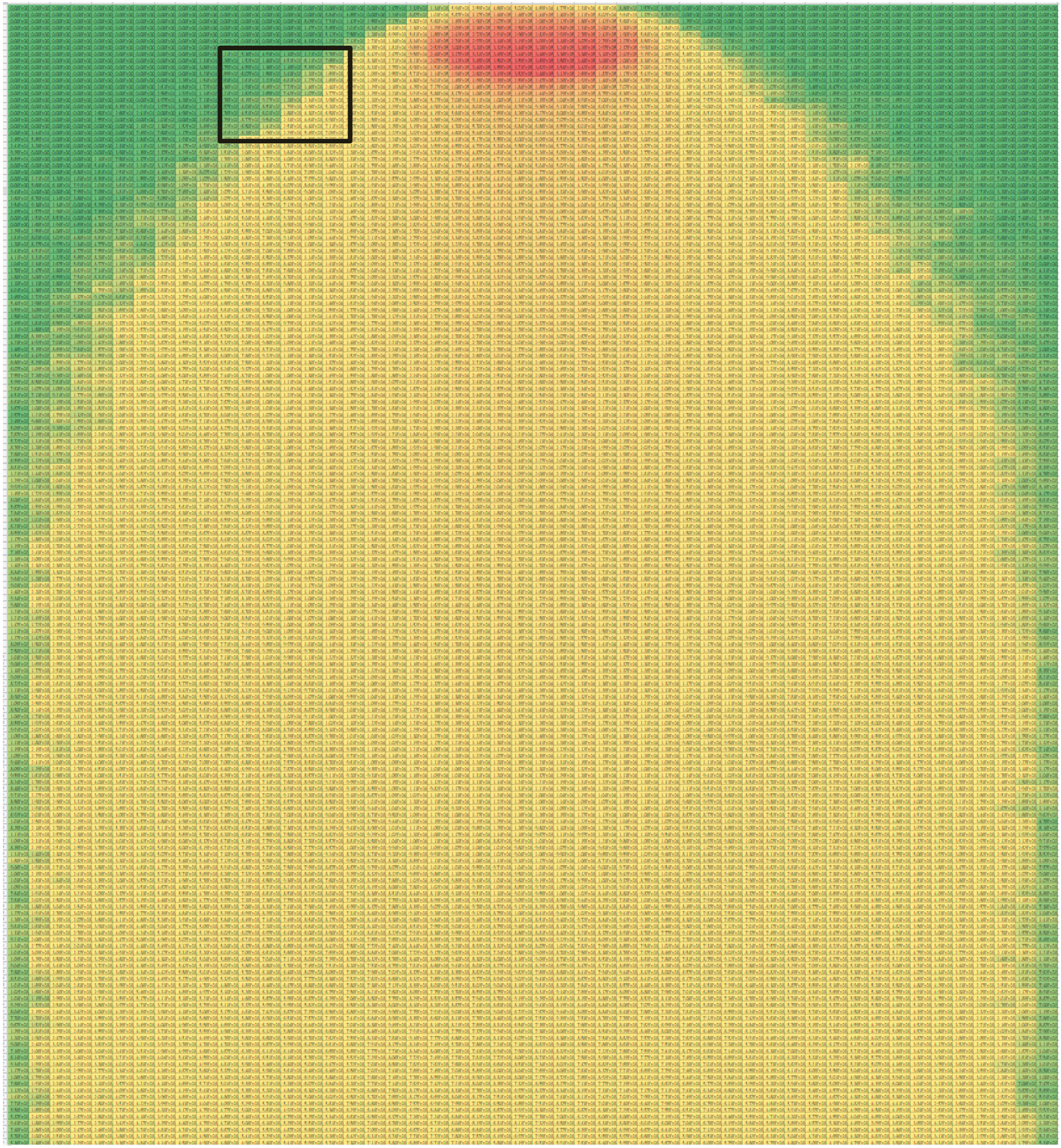

Figure 5-2 External dose rate map calculated from deposition of material, the selected area is expanded in Fig. 5-3.

1.52E+02	1.40E+02	4.51E+02	6.11E+02	7.65E+02	2.57E+03
4.59E+01	1.36E+02	1.16E+02	5.39E+02	1.75E+03	3.38E+03
6.07E+01	1.56E+02	3.43E+02	1.20E+03	1.69E+03	3.64E+03
2.61E+02	2.22E+02	6.61E+02	1.27E+03	1.69E+03	4.29E+03
1.93E+02	6.45E+02	7.72E+02	1.46E+03	2.40E+03	6.29E+03
1.62E+02	2.65E+02	7.42E+02	1.07E+03	3.77E+03	7.59E+03
6.15E+02	9.27E+02	1.28E+03	2.34E+03	3.98E+03	7.84E+03
4.03E+02	8.53E+02	1.79E+03	3.96E+03	5.20E+03	9.86E+03
4.51E+02	6.01E+02	1.88E+03	4.30E+03	6.58E+03	1.00E+04
8.77E+02	9.54E+02	2.33E+03	4.64E+03	6.90E+03	9.50E+03
6.50E+02	1.41E+03	2.53E+03	4.40E+03	7.11E+03	9.87E+03
8.28E+02	1.96E+03	2.29E+03	5.45E+03	7.09E+03	1.02E+04

Figure 5-3 Expanded view of the selected area of the external dose rate map, the dose rates displayed are in rem.

Possible Decisions Based on FidoFRMAC Results

Based on factors such as weather, technicality of the pile and the fitness of the dog, time spent on the pile will vary. The maps from FidoFRMAC show the doses that the animals would receive after one hour in a specific location. Based on these results a health and safety specialist might suggest two possible tactics. The first would be the result of the maps showing incredibly dangerous radiation levels. In this case, the handlers may choose not to allow their dogs to work in those conditions. This scenario would result in acute effects and an increase in the animal's likelihood of fatal cancer. The second tactic would be one in which the handlers allow the animals to work while aiming to receive as low of a dose as possible. Using FidoFRMAC handlers have the ability to forecast the doses for their dogs. For instance, if a dog was to work for 3 hours in a particular area with a dose rate of 0.083 Rem h^{-1}, their total dose would be 0.250 Rem. When this dose is compared to the thresholds for deterministic effects demonstrated in other dogs, one can see that the dogs would not exhibit any acute effect symptoms. Additionally, because the risk coefficients for humans and dogs are close (Recio 2010), using the risk coefficients from FGR 13 (EPA 2013) show that their risk of incurring a fatal cancer from this exposure would be marginally higher than before. Because the unit for the risk coefficients is risk m^2 μCi^{-1}, it is necessary to find the amount of material that caused the 083 rem h^{-1} radiation field. Once that value is calculated, multiplication by the risk coefficient provides the increase in risk.

$$\frac{0.25\ Rem}{3\ hours} = .083\ Rem\ h^{-1}$$

$$\frac{0.083\ Rem\ h^{-1}}{2.96\ x\ 10^{-6}\ Rem\ m^2 h^{-1} \mu Ci^{-1}} = \ 28040.5\ \mu Ci\ m^{-2}$$

$$2.5x10^{-6}\ Risk\ m^2\ \mu Ci^{-1} * \ 28040.5\ \mu Ci\ m^{-2} = 0.0701\ Risk$$

$$0.0701\%\ increase\ in\ Risk$$

From the accumulated data handlers can be used to make informed decisions on whether or not USAR dogs should be utilized. If so, what tactical measures should be made to keep them as safe as possible. It is with great hope that this tool serves its users well and keeps USAR dogs safe for years to come.

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APPENDIX A FIDOFRMAC OPERATIONS GUIDE

FidoFRMAC Purpose

Fido FRMAC is a dosimetry tool designed to provide USAR dog handlers with information regarding the dose rates from areas that are contaminated with radiological material. The tool provides a simple interface through the use of the Microsoft Excel software package. Dose Rate Conversion factors previously calculated by the author are used in conjunction with deposition data from atmospheric dispersion models like QUIC and Hotspot to produce the dose rate data for individual or mixtures of radionuclides (Brown 2012, Homann 2013). Important USAR parameters such as turn back limit and stay time are able to be computed using this tool.

What is the FRMAC and the FRMAC Manual?

The Federal Radiological Monitoring and Assessment Center (FRMAC) is a federal asset available on request by the Department of Homeland Security (DHS) and state and local agencies to respond to a nuclear or radiological incident. The FRMAC is an interagency organization with representation from the NNSA, the Department of Defense (DOD), the Environmental Protection Agency (EPA), the Department of Health and Human Services (HHS), Federal Bureau of Investigations (FBI), and other federal agencies. The Federal Radiological Monitoring and Assessment Center manual is a document prepared by representatives of the Federal and State agencies that can be expected to play major roles during a radiological emergency. The manual contains methods and values that were found to be scientifically defensible, simple and applicable to a FRMAC deployment. It also defines the technical methods to be used when performing a radiological assessment. This means it contains the tabulated reference data for all assessment conditions and methods of public protection. Unfortunately, there is not yet a section of the FRMAC manual that is dedicated to the safety of USAR animals.

Hardware and Software Requirements

A system running either Windows or Mac operating systems with Microsoft Excel or a similar spreadsheet application. (Note: If using a different spreadsheet application other than Microsoft Excel, there may be visual differences from what is shown.)

Operation

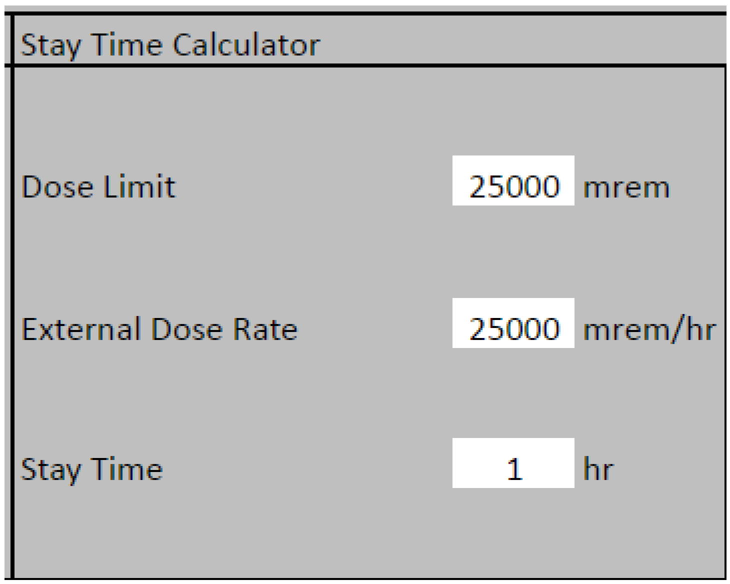
1. First, download the file
2. Navigate to the downloaded file
3. To open the dosimetry tool, double click on the FidoFRMAC.xlsx file

Stay Time Calculator

The FidoFRMAC tool features a stay time calculator based off of equation 2.1-2 in the FRMAC manual (FRMAC 2015). This parameter represents the amount of time that a worker may stay in a given location and not exceed their established dose limit based on external dose measurements made in their working location.

$$\text{Stay Time} = \frac{\text{External Dose Limit}}{\text{External Dose Rate}}$$

Where Stay Time is how long the worker will be allowed to work in a contaminated area in hours, External Dose Rate is the measured dose rate in mrem h^{-1}, and External Dose Limit is the maximum dose the worker is allowed to receive for the shift in mrem.

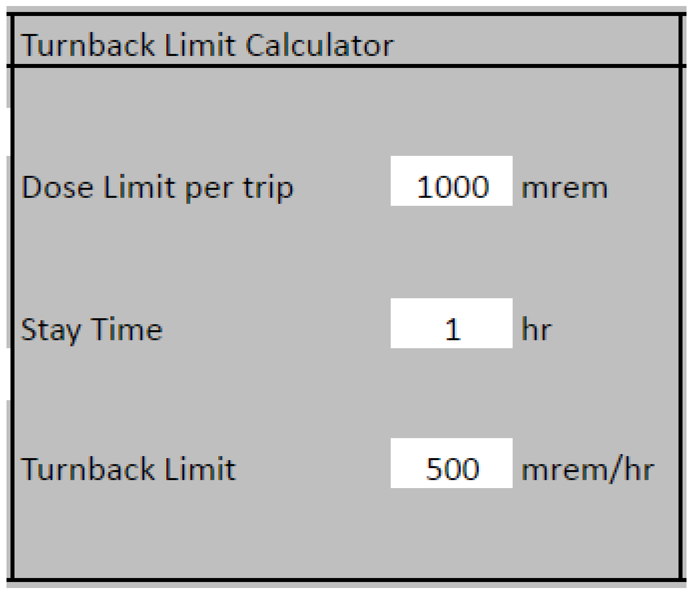


Turnback Limit Calculator

The Turn Back Limit represents the integrated external dose (or exposure) that would produce a total dose (inhalation and external) over a worker's shift. It is chosen by the decision makers for the incident and the shift length for the workers being evaluated. The equation used is based off of equation 2.1-1 in the FRMAC manual (FRMAC 2015).

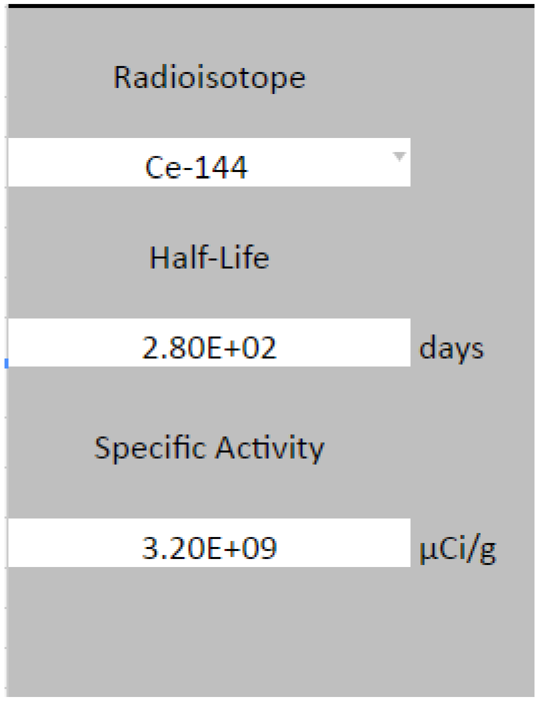
$$\text{Turn Back Limit} = \frac{\text{Dose Limit}}{\text{Stay Time}}$$

Where Turn Back Limit is the dose rate, in mrem h^{-1}, at which the worker would return. Dose Limit is the dose that the worker is allowed to receive for the shift in mrem; Stay Time is the length of time, in hours, that a worker is expected to work in the contaminated area.



Dosimetry Data

The FRMAC manual has radiological data on 44 radionuclides. Radiological data for these radionuclides of interest is displayed upon selection of a radionuclide from the dropdown list. Specific activity, the activity of a radionuclide per unit mass, is displayed along with the half-life of the radionuclide in days. Additionally, dose rate conversion factors for the selected radionuclide are shown.



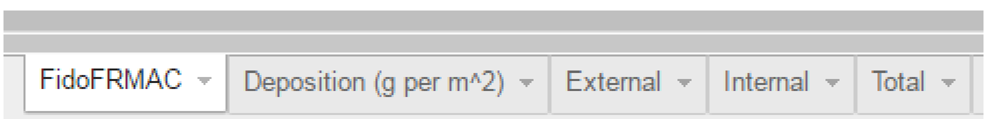
External dose rate conversion factors have been calculated to be suitable for the average height of FEMA recommended USAR dog breeds at forty cm. Internal dose rate conversion factors have been calculated for inhalation of resuspended material at twenty cm. During missions, USAR dogs do not breath primarily with their noses on the ground as is commonly thought. Breathing is done through the mouth before localizing on a scent, at which time the dog then utilizes his nose to zero in on a human. Twenty cm was chosen as the average between searching height and localizing height. Total dose rate conversion factors are the combination of external and internal doses.

The FidoFRMAC dosimetry tool can be used in conjunction with the output from atmospheric dispersion simulations to calculate the dose rates at given points. (Note: This will be discussed further in the next section.) Calculated maximum and minimum dose rates for the three dose pathways are displayed next to their respective dose rate conversion factors.

External Dose Parameter		Max Dose Rate (mrem/hr)	Min. Dose Rates (mrem/hr)
1.90E-01	mrem*m^2/µCi	3.71E+05	7.55E+00
Internal Dose Parameter			
1.50E-01	mrem*m^2/µCi	2.93E+05	5.96E+00
Total Dose Parameter			
3.40E-01	mrem*m^2/µCi	6.64E+05	1.35E+01

Dose Rate Visualizations

When using the data from an atmospheric dispersion simulation, the user can copy and paste the deposition data into the sheet titled "Deposition". The sheets labeled 'External', 'Internal', and 'Total' utilize this deposition data along with their respective dose rate conversion factors to compute the dose rate resulting from the deposition.



Through the use of conditional formatting we add color and are able to see the variations in dose rate to reveal particular areas that may need to be avoided or that can be explored. This gives USAR dog handlers added information on how they choose to utilize their assets in situations that involve radiological contamination. This information can then be used to calculate.

APPENDIX B PHOTON DOSE RATE CONVERSION FACTORS

Radionuclide	Photon Energy (MeV)	Dose Conversion Factor at Energy E	Frequency Y(i) Bq s^{-1}	Dose Conversion Factor (Sv hr^{-1} μCi m^{-2})
^{241}Am	2.63E-02	6.20E-05	2.27E-02	1.41E-06
	5.95E-02	4.49E-05	3.59E-01	1.61E-05
	1.39E-02	0.00E+00	3.65E-01	0.00E+00
				1.75E-05
^{140}Ba	3.00E-02	5.13E-05	1.41E-01	7.23E-06
	1.63E-01	9.97E-05	6.22E-02	6.20E-06
	3.05E-01	1.79E-04	4.29E-02	7.66E-06
	4.24E-01	2.38E-04	3.15E-02	7.51E-06
	4.38E-01	2.45E-04	1.93E-02	4.73E-06
	5.37E-01	2.91E-04	2.44E-01	7.09E-05
	3.34E-02	4.85E-05	1.01E-02	4.90E-07
	4.70E-03	0.00E+00	1.35E-01	0.00E+00
				1.05E-04
^{141}Ce	1.45E-01	8.94E-05	4.84E-01	4.33E-05
	3.60E-02	4.64E-05	8.90E-02	4.13E-06
	3.56E-02	4.68E-05	4.87E-02	2.28E-06
	4.07E-02	4.32E-05	3.40E-02	1.47E-06

	5.00E-03	0.00E+00	2.51E-02	0.00E+00
				5.12E-05
^{144}Ce	8.01E-02	5.35E-05	1.36E-02	7.27E-07
	1.34E-01	8.33E-05	1.11E-01	9.24E-06
	3.60E-02	4.64E-05	4.50E-02	2.09E-06
	3.56E-02	4.68E-05	2.47E-02	1.16E-06
	4.07E-02	4.32E-05	1.72E-02	7.42E-07
	5.00E-03	0.00E+00	1.52E-02	0.00E+00
				1.40E-05
^{242}Cm	1.43E-02	0.00E+00	9.86E-02	0.00E+00
				0.00E+00
^{244}Cm	1.43E-02	0.00E+00	9.05E-02	0.00E+00
				0.00E+00
^{60}Co	1.17E+00	5.30E-04	9.98E-01	5.29E-04
	1.33E+00	5.81E-04	1.00E+00	5.81E-04
				1.10E-03
^{134}Cs	4.75E-01	2.62E-04	1.48E-02	3.88E-06
	5.63E-01	3.02E-04	8.34E-02	2.52E-05
	5.69E-01	3.05E-04	1.54E-01	4.70E-05

	6.05E-01	3.21E-04	9.76E-01	3.13E-04
	7.96E-01	3.98E-04	8.55E-01	3.41E-04
	8.02E-01	4.01E-04	8.69E-02	3.48E-05
	1.17E+00	5.30E-04	1.79E-02	9.48E-06
	1.37E+00	5.94E-04	3.02E-02	1.79E-05
				7.92E-04
^{136}Cs	6.69E-02	4.79E-05	4.79E-02	2.29E-06
	8.64E-02	5.69E-05	5.18E-02	2.95E-06
	1.53E-01	9.39E-05	5.75E-02	5.40E-06
	1.64E-01	1.00E-04	3.39E-02	3.40E-06
	1.77E-01	1.08E-04	9.97E-02	1.07E-05
	2.74E-01	1.62E-04	1.11E-01	1.79E-05
	3.41E-01	1.97E-04	4.22E-01	8.31E-05
	8.19E-01	4.07E-04	9.97E-01	4.06E-04
	1.05E+00	4.91E-04	7.98E-01	3.92E-04
	1.24E+00	5.52E-04	2.00E-01	1.10E-04
				1.00E-03

^{137}Cs	6.62E-01	3.44E-04	8.51E-01	2.93E-04
	3.22E-02	4.95E-05	3.67E-02	1.82E-06
	3.18E-02	4.98E-05	1.99E-02	9.92E-07
	3.64E-02	4.61E-05	1.35E-02	6.23E-07
				2.96E-04
^{153}Gd	6.97E-02	4.91E-05	2.42E-02	1.19E-06
	9.74E-02	6.29E-05	2.90E-01	1.82E-05
	1.03E-01	6.60E-05	2.11E-01	1.39E-05
	4.15E-02	4.31E-05	6.25E-01	2.69E-05
	4.09E-02	4.31E-05	3.46E-01	1.49E-05
	4.70E-02	4.28E-05	2.48E-01	1.06E-05
	5.90E-03	0.00E+00	2.27E-01	0.00E+00
				8.58E-05
^{129}I	3.96E-02	4.35E-05	7.51E-02	3.27E-06
	3.96E-02	4.35E-05	7.51E-02	3.27E-06
	2.98E-02	5.19E-05	3.61E-01	1.88E-05
	2.95E-02	5.29E-05	1.95E-01	1.03E-05
	3.36E-02	4.84E-05	1.29E-01	6.24E-06
	4.10E-03	0.00E+00	7.82E-02	0.00E+00
	3.96E-02	4.35E-05	7.51E-02	3.27E-06
	3.96E-02	4.35E-05	7.51E-02	3.27E-06

	2.98E-02	5.19E-05	3.61E-01	1.88E-05
	2.95E-02	5.29E-05	1.95E-01	1.03E-05
	3.36E-02	4.84E-05	1.29E-01	6.24E-06
	4.10E-03	0.00E+00	7.82E-02	0.00E+00
				8.37E-05
^{131}I	8.02E-02	5.35E-05	2.62E-02	1.40E-06
	2.84E-01	1.67E-04	6.12E-02	1.02E-05
	3.65E-01	2.09E-04	8.15E-01	1.70E-04
	6.37E-01	3.34E-04	7.16E-02	2.39E-05
	7.23E-01	3.69E-04	1.77E-02	6.53E-06
	2.98E-02	5.19E-05	2.68E-02	1.39E-06
	2.95E-02	5.28E-05	1.45E-02	7.65E-07
				2.15E-04
^{132}I	2.63E-01	1.56E-04	1.28E-02	1.99E-06
	5.06E-01	2.77E-04	4.94E-02	1.37E-05
	5.23E-01	2.84E-04	1.60E-01	4.55E-05
	5.47E-01	2.95E-04	1.14E-02	3.36E-06
	6.21E-01	3.28E-04	1.58E-02	5.17E-06
	6.30E-01	3.31E-04	1.33E-01	4.40E-05
	6.51E-01	3.40E-04	2.57E-02	8.73E-06
	6.68E-01	3.47E-04	9.87E-01	3.42E-04

	6.70E-01	3.47E-04	4.64E-02	1.61E-05
	6.71E-01	3.48E-04	3.45E-02	1.20E-05
	7.27E-01	3.70E-04	2.17E-02	8.04E-06
	7.27E-01	3.70E-04	3.16E-02	1.17E-05
	7.28E-01	3.71E-04	1.58E-02	5.86E-06
	7.73E-01	3.89E-04	7.56E-02	2.94E-05
	7.80E-01	3.92E-04	1.18E-02	4.62E-06
	8.10E-01	4.04E-04	2.57E-02	1.04E-05
	8.12E-01	4.05E-04	5.53E-02	2.24E-05
	8.77E-01	4.29E-04	1.04E-02	4.46E-06
	9.55E-01	4.58E-04	1.76E-01	8.06E-05
	1.14E+00	5.20E-04	3.01E-02	1.57E-05
	1.14E+00	5.20E-04	1.35E-02	7.02E-06
	1.17E+00	5.30E-04	1.09E-02	5.77E-06
	1.29E+00	5.68E-04	1.13E-02	6.42E-06
	1.30E+00	5.72E-04	1.88E-02	1.07E-05

	1.37E+00	5.94E-04	2.47E-02	1.47E-05
	1.40E+00	6.04E-04	7.01E-02	4.23E-05
	1.44E+00	6.17E-04	1.40E-02	8.63E-06
	1.92E+00	7.52E-04	1.23E-02	9.25E-06
	2.00E+00	7.74E-04	1.14E-02	8.82E-06
				7.99E-04
^{133}I	5.30E-01	2.88E-04	8.70E-01	2.50E-04
	7.07E-01	3.62E-04	1.51E-02	5.47E-06
	8.56E-01	4.21E-04	1.24E-02	5.22E-06
	8.75E-01	4.28E-04	4.51E-02	1.93E-05
	1.24E+00	5.52E-04	1.51E-02	8.34E-06
	1.30E+00	5.72E-04	2.35E-02	1.34E-05
				3.02E-04
^{134}I	1.35E-01	8.38E-05	4.31E-02	3.61E-06

	2.36E-01	1.41E-04	2.13E-02	3.00E-06
	4.06E-01	2.30E-04	7.37E-02	1.69E-05
	4.33E-01	2.43E-04	4.15E-02	1.01E-05
	4.59E-01	2.55E-04	1.31E-02	3.34E-06
	4.89E-01	2.69E-04	1.45E-02	3.90E-06
	5.14E-01	2.80E-04	2.24E-02	6.28E-06
	5.41E-01	2.92E-04	7.66E-02	2.24E-05
	5.95E-01	3.17E-04	1.11E-01	3.52E-05
	6.22E-01	3.28E-04	1.06E-01	3.48E-05
	6.28E-01	3.30E-04	2.22E-02	7.33E-06
	6.77E-01	3.50E-04	7.94E-02	2.78E-05
	7.31E-01	3.72E-04	1.83E-02	6.81E-06
	7.67E-01	3.87E-04	4.15E-02	1.60E-05
	8.47E-01	4.18E-04	9.57E-01	4.00E-04
	8.57E-01	4.21E-04	6.70E-02	2.82E-05
	8.84E-01	4.32E-04	6.50E-01	2.80E-04
	9.48E-01	4.56E-04	4.01E-02	1.83E-05
	9.75E-01	4.66E-04	4.78E-02	2.23E-05
	1.04E+00	4.88E-04	2.03E-02	9.90E-06

	1.07E+0 0	4.98E-04	1.49E-01	7.41E-05
	1.14E+0 0	5.20E-04	9.09E-02	4.73E-05
	1.46E+0 0	6.23E-04	2.30E-02	1.43E-05
	1.61E+0 0	6.66E-04	4.31E-02	2.87E-05
	1.74E+0 0	7.02E-04	2.56E-02	1.80E-05
	1.81E+0 0	7.22E-04	5.55E-02	4.00E-05
				1.20E-03
^{135}I	2.21E-01	1.33E-04	1.75E-02	2.32E-06
	2.89E-01	1.70E-04	3.10E-02	5.27E-06
	4.18E-01	2.35E-04	3.53E-02	8.31E-06
	5.47E-01	2.95E-04	7.15E-02	2.11E-05
	8.37E-01	4.14E-04	6.69E-02	2.77E-05
	9.73E-01	4.65E-04	1.21E-02	5.63E-06
	1.04E+0 0	4.88E-04	7.95E-02	3.88E-05

	1.10E+0 0	5.07E-04	1.61E-02	8.17E-06
	1.12E+0 0	5.14E-04	3.62E-02	1.86E-05
	1.13E+0 0	5.17E-04	2.26E-01	1.17E-04
	1.26E+0 0	5.59E-04	2.87E-01	1.60E-04
	1.46E+0 0	6.23E-04	8.67E-02	5.40E-05
	1.50E+0 0	6.36E-04	1.08E-02	6.87E-06
	1.57E+0 0	6.55E-04	1.29E-02	8.45E-06
	1.68E+0 0	6.86E-04	9.56E-02	6.56E-05
	1.71E+0 0	6.94E-04	4.10E-02	2.85E-05
	1.79E+0 0	7.16E-04	7.72E-02	5.53E-05
				6.32E-04

^{192}Ir	2.06E-02	7.86E-05	3.31E-02	2.60E-06
	4.85E-02	4.27E-05	3.19E-02	1.36E-06
	2.96E-01	1.74E-04	2.87E-01	4.99E-05
	3.09E-01	1.81E-04	2.97E-01	5.36E-05
	3.17E-01	1.85E-04	8.29E-01	1.53E-04
	4.68E-01	2.59E-04	4.78E-01	1.24E-04
	5.89E-01	3.14E-04	4.52E-01	1.42E-04
	6.04E-01	3.21E-04	8.22E-01	2.64E-04
	6.13E-01	3.24E-04	5.34E-02	1.73E-05
	6.68E-01	3.47E-04	4.54E-02	1.57E-05
	6.51E-02	4.71E-05	2.65E-02	1.25E-06
	7.57E-02	5.16E-05	1.97E-02	1.02E-06
				8.25E-04
^{99}Mo	4.06E-02	4.32E-05	1.06E-02	4.58E-07
	1.81E-01	1.10E-04	6.14E-02	6.76E-06
	3.66E-01	2.10E-04	1.20E-02	2.52E-06
	7.40E-01	3.76E-04	1.23E-01	4.62E-05
	7.78E-01	3.91E-04	4.30E-02	1.68E-05
	1.84E-02	8.88E-05	1.81E-02	1.61E-06
				7.44E-05
^{95}Nb	7.69E-01	3.87E-04	9.98E-01	3.87E-04

				3.87E-04
^{237}Np	2.94E-02	5.30E-05	1.41E-01	7.48E-06
	8.65E-02	5.69E-05	1.24E-01	7.06E-06
	9.59E-02	6.21E-05	2.73E-02	1.69E-06
	9.23E-02	6.01E-05	1.70E-02	1.02E-06
	1.08E-01	6.88E-05	1.31E-02	9.01E-07
	1.33E-02	0.00E+00	4.93E-01	0.00E+00
				1.82E-05
^{239}Np	6.15E-02	4.56E-05	1.30E-02	5.93E-07
	1.06E-01	6.76E-05	2.53E-01	1.71E-05
	2.10E-01	1.27E-04	3.36E-02	4.25E-06
	2.28E-01	1.36E-04	1.07E-01	1.46E-05
	2.78E-01	1.64E-04	1.45E-01	2.38E-05
	3.16E-01	1.84E-04	1.60E-02	2.95E-06
	3.34E-01	1.93E-04	2.06E-02	3.98E-06
	1.04E-01	6.65E-05	2.08E-01	1.38E-05
	9.96E-02	6.41E-05	1.31E-01	8.39E-06
	1.17E-01	7.38E-05	1.03E-01	7.60E-06
	1.43E-02	0.00E+00	4.46E-01	0.00E+00
				9.71E-05
^{238}Pu	1.36E-02	0.00E+00	1.02E-01	0.00E+00

				0.00E+00
^{239}Pu	1.36E-02	0.00E+00	4.29E-02	0.00E+00
				0.00E+00
^{103}Ru	4.97E-01	2.73E-04	9.10E-01	2.48E-04
	6.10E-01	3.23E-04	5.76E-02	1.86E-05
	2.02E-02	7.97E-05	4.88E-02	3.89E-06
	2.01E-02	8.00E-05	2.58E-02	2.06E-06
				2.73E-04
^{127}Sb	6.11E-02	4.55E-05	1.44E-02	6.55E-07
	2.52E-01	1.50E-04	8.50E-02	1.27E-05
	2.91E-01	1.71E-04	2.02E-02	3.46E-06
	4.12E-01	2.33E-04	3.83E-02	8.91E-06
	4.73E-01	2.61E-04	2.58E-01	6.74E-05
	5.43E-01	2.93E-04	2.94E-02	8.62E-06
	6.04E-01	3.21E-04	4.45E-02	1.43E-05
	6.86E-01	3.54E-04	3.68E-01	1.30E-04
	7.84E-01	3.94E-04	1.51E-01	5.94E-05
				3.06E-04
^{129}Sb	1.80E-01	1.09E-04	2.84E-02	3.11E-06
	3.59E-01	2.06E-04	2.39E-02	4.93E-06
	4.05E-01	2.29E-04	1.17E-02	2.68E-06

	5.23E-01	2.84E-04	1.55E-02	4.41E-06
	6.34E-01	3.33E-04	2.53E-02	8.42E-06
	6.54E-01	3.41E-04	2.97E-02	1.01E-05
	6.83E-01	3.53E-04	5.76E-02	2.03E-05
	7.61E-01	3.84E-04	4.32E-02	1.66E-05
	7.73E-01	3.89E-04	2.82E-02	1.10E-05
	7.86E-01	3.94E-04	1.07E-02	4.22E-06
	7.87E-01	3.95E-04	1.74E-02	6.87E-06
	8.13E-01	4.05E-04	4.82E-01	1.95E-04
	8.20E-01	4.08E-04	1.39E-02	5.66E-06
	8.77E-01	4.29E-04	2.75E-02	1.18E-05
	9.15E-01	4.43E-04	2.33E-01	1.03E-04
	9.67E-01	4.63E-04	8.96E-02	4.15E-05
	1.03E+00	4.85E-04	1.51E-01	7.32E-05
				5.23E-04
^{75}Se	6.61E-02	4.76E-05	1.11E-02	5.28E-07
	9.67E-02	6.25E-05	3.45E-02	2.16E-06
	1.21E-01	7.60E-05	1.72E-01	1.31E-05
	1.36E-01	8.44E-05	5.85E-01	4.94E-05
	1.99E-01	1.20E-04	1.50E-02	1.81E-06

	2.65E-01	1.57E-04	5.89E-01	9.23E-05
	2.80E-01	1.65E-04	2.50E-01	4.13E-05
	3.04E-01	1.78E-04	1.31E-02	2.33E-06
	4.01E-01	2.27E-04	1.14E-01	2.59E-05
	1.05E-02	0.00E+00	3.21E-01	0.00E+00
	1.05E-02	0.00E+00	1.65E-01	0.00E+00
	1.17E-02	0.00E+00	7.62E-02	0.00E+00
				2.29E-04
^{129m}Te	2.75E-02	5.86E-05	1.48E-01	8.67E-06
	2.72E-02	5.94E-05	7.93E-02	4.71E-06
	3.10E-02	5.05E-05	5.15E-02	2.60E-06
	3.80E-03	0.00E+00	4.60E-02	0.00E+00
	6.96E-01	3.58E-04	2.99E-02	1.07E-05
				2.67E-05
^{131m}Te	8.11E-02	5.40E-05	3.92E-02	2.12E-06
	1.02E-01	6.54E-05	7.66E-02	5.01E-06
	1.50E-01	9.22E-05	4.89E-02	4.51E-06
	2.01E-01	1.22E-04	7.28E-02	8.85E-06
	2.41E-01	1.44E-04	7.32E-02	1.05E-05
	2.79E-01	1.64E-04	1.72E-02	2.83E-06
	3.34E-01	1.93E-04	9.22E-02	1.78E-05

	3.65E-01	2.09E-04	1.16E-02	2.43E-06
	4.52E-01	2.51E-04	1.49E-02	3.75E-06
	4.63E-01	2.57E-04	1.76E-02	4.52E-06
	5.86E-01	3.13E-04	1.90E-02	5.94E-06
	6.65E-01	3.45E-04	4.18E-02	1.44E-05
	7.13E-01	3.65E-04	1.38E-02	5.03E-06
	7.44E-01	3.77E-04	1.53E-02	5.77E-06
	7.74E-01	3.89E-04	3.68E-01	1.43E-04
	7.83E-01	3.93E-04	7.51E-02	2.95E-05
	7.94E-01	3.98E-04	1.34E-01	5.33E-05
	8.23E-01	4.09E-04	5.90E-02	2.41E-05
	8.52E-01	4.20E-04	1.99E-01	8.35E-05
	9.10E-01	4.41E-04	3.17E-02	1.40E-05
	9.21E-01	4.45E-04	1.16E-02	5.17E-06
	1.06E+00	4.94E-04	1.49E-02	7.37E-06
	1.13E+00	5.17E-04	1.10E-01	5.69E-05
	1.15E+00	5.23E-04	1.46E-02	7.64E-06

	1.21E+00	5.43E-04	9.41E-02	5.11E-05
	1.65E+00	6.77E-04	1.20E-02	8.13E-06
	1.89E+00	7.44E-04	1.31E-02	9.74E-06
	2.00E+00	7.74E-04	1.94E-02	1.50E-05
	2.86E+00	9.86E-04	5.21E-02	5.13E-05
				6.54E-04
^{132}Te	4.97E-02	4.26E-05	1.50E-01	6.39E-06
	1.12E-01	7.10E-05	1.74E-01	1.24E-05
	1.16E-01	7.32E-05	1.96E-01	1.44E-05
	2.28E-01	1.36E-04	8.80E-01	1.20E-04
	2.86E-02	5.54E-05	3.84E-01	2.13E-05
	2.83E-02	5.62E-05	2.07E-01	1.16E-05
	3.23E-02	4.94E-05	1.36E-01	6.72E-06
	3.90E-03	0.00E+00	7.83E-02	0.00E+00
				1.93E-04
^{170}Tm	8.43E-02	5.57E-05	2.48E-02	1.38E-06

	5.24E-02	4.32E-05	1.71E-02	7.38E-07
	7.40E-03	0.00E+00	2.93E-02	0.00E+00
				2.12E-06
^{169}Yb	6.30E-02	4.63E-05	1.08E-02	5.00E-07
	6.31E-02	4.63E-05	4.36E-01	2.02E-05
	9.36E-02	6.08E-05	2.58E-02	1.57E-06
	1.10E-01	6.99E-05	1.74E-01	1.22E-05
	1.18E-01	7.43E-05	1.87E-02	1.39E-06
	1.31E-01	8.16E-05	1.14E-01	9.30E-06
	1.77E-01	1.08E-04	2.23E-01	2.40E-05
	1.98E-01	1.20E-04	3.59E-01	4.30E-05
	2.61E-01	1.55E-04	1.68E-02	2.60E-06
	3.08E-01	1.80E-04	1.00E-01	1.80E-05
	5.07E-02	4.28E-05	9.23E-01	3.95E-05
	4.98E-02	4.26E-05	5.23E-01	2.23E-05
	5.75E-02	4.44E-05	3.80E-01	1.69E-05
	7.20E-03	0.00E+00	4.77E-01	0.00E+00
				2.11E-04
^{95}Zr	7.24E-01	3.69E-04	4.43E-01	1.64E-04
	7.57E-01	3.83E-04	5.44E-01	2.08E-04
				3.72E-04

APPENDIX C CONVERSION AND AUGER ELECTRON DOSE RATE CONVERSION FACTORS

Radionuclide	Electron Energy (MeV)	Dose Conversion Factor at Energy E	Frequency Y(i) Bq s^{-1}	Dose Conversion Factor (Sv hr^{-1} μCi m^{-2})
^{241}Am	3.90E-03	0.00E+00	1.36E-01	0.00E+00
	2.06E-02	0.00E+00	3.63E-02	0.00E+00
	1.08E-02	0.00E+00	1.74E-01	0.00E+00
	2.75E-02	0.00E+00	4.41E-02	0.00E+00
	2.10E-02	0.00E+00	9.05E-02	0.00E+00
	3.77E-02	0.00E+00	2.39E-02	0.00E+00
	3.31E-02	0.00E+00	8.90E-03	0.00E+00
	4.98E-02	0.00E+00	2.40E-03	0.00E+00
	5.41E-02	0.00E+00	8.87E-04	0.00E+00
	3.71E-02	0.00E+00	3.02E-01	0.00E+00
	5.38E-02	0.00E+00	8.11E-02	0.00E+00
	5.80E-02	0.00E+00	3.37E-02	0.00E+00
	7.65E-02	0.00E+00	2.30E-03	0.00E+00
	9.33E-02	0.00E+00	6.35E-04	0.00E+00
	1.01E-02	0.00E+00	3.49E-01	0.00E+00
				0.00E+00

^{140}Ba	7.60E-03	0.00E+00	5.26E-01	0.00E+00
	1.25E-02	0.00E+00	1.10E-01	0.00E+00
	1.36E-02	0.00E+00	2.82E-02	0.00E+00
	2.37E-02	0.00E+00	6.01E-01	0.00E+00
	2.86E-02	0.00E+00	1.25E-01	0.00E+00
	2.97E-02	0.00E+00	3.21E-02	0.00E+00
	1.24E-01	0.00E+00	1.47E-02	0.00E+00
	2.66E-01	2.50E-03	1.90E-03	4.65E-06
	3.80E-03	0.00E+00	1.01E+00	0.00E+00
	4.98E-01	5.70E-03	2.50E-03	1.43E-05
				1.90E-05
^{141}Ce	1.04E-01	0.00E+00	1.88E-01	0.00E+00
	1.39E-01	0.00E+00	2.59E-02	0.00E+00
	1.44E-01	0.00E+00	5.40E-03	0.00E+00
	1.45E-01	0.00E+00	1.50E-03	0.00E+00
	2.94E-02	0.00E+00	1.61E-02	0.00E+00
	4.10E-03	0.00E+00	1.64E-01	0.00E+00
				0.00E+00
^{144}Ce	2.67E-02	0.00E+00	7.50E-03	0.00E+00
	3.42E-02	0.00E+00	5.60E-03	0.00E+00
	5.22E-02	0.00E+00	6.20E-03	0.00E+00

	3.81E-02	0.00E+00	2.89E-02	0.00E+00
	7.33E-02	0.00E+00	4.00E-03	0.00E+00
	9.15E-02	0.00E+00	5.47E-02	0.00E+00
	1.27E-01	0.00E+00	7.50E-03	0.00E+00
	1.32E-01	0.00E+00	1.60E-03	0.00E+00
	2.94E-02	0.00E+00	8.10E-03	0.00E+00
	4.10E-03	0.00E+00	9.96E-02	0.00E+00
				0.00E+00
^{242}Cm	2.10E-02	0.00E+00	1.89E-01	0.00E+00
	3.82E-02	0.00E+00	5.24E-02	0.00E+00
	4.25E-02	0.00E+00	1.74E-02	0.00E+00
	1.03E-02	0.00E+00	9.06E-02	0.00E+00
				0.00E+00
^{244}Cm	1.97E-02	0.00E+00	1.73E-01	0.00E+00
	3.69E-02	0.00E+00	4.82E-02	0.00E+00
	4.13E-02	0.00E+00	1.69E-02	0.00E+00
	7.58E-02	0.00E+00	1.71E-04	0.00E+00
	1.03E-02	0.00E+00	8.31E-02	0.00E+00
				0.00E+00
^{60}Co	1.17E+00	6.90E-03	1.50E-04	1.04E-06
	1.32E+00	7.10E-03	1.14E-04	8.09E-07

				1.84E-06
^{134}Cs	5.26E-01	5.80E-03	5.08E-04	2.95E-06
	5.32E-01	5.80E-03	1.30E-03	7.25E-06
	5.67E-01	5.90E-03	4.90E-03	2.90E-05
	5.99E-01	6.00E-03	7.03E-04	4.22E-06
	7.58E-01	6.40E-03	2.20E-03	1.41E-05
	7.90E-01	6.40E-03	2.99E-04	1.91E-06
	7.65E-01	6.40E-03	2.21E-04	1.41E-06
				6.08E-05
^{136}Cs	2.94E-02	0.00E+00	2.82E-02	0.00E+00
	6.09E-02	0.00E+00	4.00E-03	0.00E+00
	4.89E-02	0.00E+00	1.51E-02	0.00E+00
	8.04E-02	0.00E+00	2.10E-03	0.00E+00
	7.22E-02	0.00E+00	2.00E-03	0.00E+00
	1.16E-01	0.00E+00	1.84E-02	0.00E+00
	1.47E-01	0.00E+00	5.20E-03	0.00E+00
	1.52E-01	0.00E+00	1.10E-03	0.00E+00
	1.27E-01	0.00E+00	3.80E-02	0.00E+00
	1.58E-01	0.00E+00	3.02E-02	0.00E+00
	1.63E-01	0.00E+00	6.80E-03	0.00E+00
	1.64E-01	0.00E+00	1.80E-03	0.00E+00

	1.39E-01	0.00E+00	4.50E-03	0.00E+00
	2.36E-01	1.40E-03	1.60E-03	2.17E-06
	3.03E-01	3.90E-03	1.05E-02	4.10E-05
	3.35E-01	4.30E-03	1.80E-03	7.78E-06
	7.81E-01	6.40E-03	2.40E-03	1.54E-05
	8.13E-01	6.50E-03	3.29E-04	2.14E-06
	1.01E+00	6.80E-03	1.10E-03	7.62E-06
	1.04E+00	6.80E-03	1.44E-04	9.79E-07
	1.20E+00	7.00E-03	2.00E-04	1.40E-06
	2.64E-02	0.00E+00	1.23E-02	0.00E+00
	3.70E-03	0.00E+00	1.38E-01	0.00E+00
				7.85E-05
^{137}Cs	6.24E-01	6.10E-03	7.79E-02	4.75E-04
	6.56E-01	6.20E-03	1.40E-02	8.68E-05
	6.60E-01	6.20E-03	3.00E-03	1.86E-05
	6.61E-01	6.20E-03	7.48E-04	4.64E-06
	2.64E-02	0.00E+00	7.80E-03	0.00E+00
	3.70E-03	0.00E+00	7.40E-02	0.00E+00
				5.85E-04
^{153}Gd	2.12E-02	0.00E+00	1.08E-01	0.00E+00
	6.16E-02	0.00E+00	1.77E-02	0.00E+00

	6.79E-02	0.00E+00	3.90E-03	0.00E+00
	6.93E-02	0.00E+00	1.10E-03	0.00E+00
	3.49E-02	0.00E+00	4.70E-03	0.00E+00
	7.53E-02	0.00E+00	2.20E-03	0.00E+00
	8.16E-02	0.00E+00	5.06E-04	0.00E+00
	4.10E-02	0.00E+00	1.50E-03	0.00E+00
	4.89E-02	0.00E+00	7.48E-02	0.00E+00
	8.94E-02	0.00E+00	1.11E-02	0.00E+00
	9.56E-02	0.00E+00	2.40E-03	0.00E+00
	9.71E-02	0.00E+00	6.64E-04	0.00E+00
	5.47E-02	0.00E+00	3.06E-01	0.00E+00
	9.51E-02	0.00E+00	4.56E-02	0.00E+00
	1.01E-01	0.00E+00	9.90E-03	0.00E+00
	1.03E-01	0.00E+00	2.90E-03	0.00E+00
	3.37E-02	0.00E+00	9.26E-02	0.00E+00
	4.70E-03	0.00E+00	1.12E+00	0.00E+00
				0.00E+00
^{129}I	5.00E-03	0.00E+00	7.71E-01	0.00E+00
	3.41E-02	0.00E+00	1.06E-01	0.00E+00
	3.84E-02	0.00E+00	2.15E-02	0.00E+00
	5.00E-03	0.00E+00	7.71E-01	0.00E+00

	3.41E-02	0.00E+00	1.06E-01	0.00E+00
	3.84E-02	0.00E+00	2.15E-02	0.00E+00
	2.46E-02	0.00E+00	8.60E-02	0.00E+00
	3.40E-03	0.00E+00	7.24E-01	0.00E+00
	5.00E-03	0.00E+00	7.71E-01	0.00E+00
	3.41E-02	0.00E+00	1.06E-01	0.00E+00
	3.84E-02	0.00E+00	2.15E-02	0.00E+00
	5.00E-03	0.00E+00	7.71E-01	0.00E+00
	3.41E-02	0.00E+00	1.06E-01	0.00E+00
	3.84E-02	0.00E+00	2.15E-02	0.00E+00
	2.46E-02	0.00E+00	8.60E-02	0.00E+00
	3.40E-03	0.00E+00	7.24E-01	0.00E+00
				0.00E+00
^{131}I	4.56E-02	0.00E+00	3.14E-02	0.00E+00
	7.47E-02	0.00E+00	4.50E-03	0.00E+00
	2.50E-01	2.00E-03	2.50E-03	5.00E-06
	3.30E-01	4.20E-03	1.56E-02	6.55E-05
	3.59E-01	4.60E-03	2.40E-03	1.12E-05
	3.40E-03	0.00E+00	5.62E-02	0.00E+00
				8.17E-05
^{132}I	4.88E-01	5.70E-03	1.40E-03	7.92E-06

	6.33E-01	6.10E-03	3.50E-03	2.14E-05
	7.38E-01	6.30E-03	1.90E-03	1.19E-05
				4.12E-05
^{133}I	4.95E-01	5.70E-03	7.00E-03	3.97E-05
	5.24E-01	5.80E-03	8.32E-04	4.83E-06
				4.45E-05
^{134}I	1.01E-01	0.00E+00	1.30E-02	0.00E+00
	8.13E-01	6.50E-03	1.90E-03	1.25E-05
	8.50E-01	6.50E-03	1.20E-03	7.74E-06
				2.03E-05
^{135}I	1.23E+00	7.00E-03	2.99E-04	2.09E-06
				2.09E-06
^{192}Ir	1.32E-01	0.00E+00	5.20E-03	0.00E+00
	1.93E-01	1.00E-04	3.60E-03	3.61E-07
	4.11E-01	5.30E-03	6.23E-04	3.30E-06
	6.90E-03	0.00E+00	3.38E-02	0.00E+00
	2.18E-01	8.00E-04	1.87E-02	1.50E-05
	2.82E-01	3.10E-03	8.60E-03	2.66E-05
	2.93E-01	3.60E-03	2.20E-03	7.74E-06
	2.30E-01	1.20E-03	1.79E-02	2.15E-05
	2.95E-01	3.60E-03	7.60E-03	2.75E-05

	3.05E-01	3.90E-03	1.90E-03	7.45E-06
	2.38E-01	1.50E-03	4.43E-02	6.65E-05
	3.03E-01	3.90E-03	1.92E-02	7.49E-05
	3.13E-01	4.00E-03	4.80E-03	1.92E-05
	3.16E-01	4.00E-03	1.40E-03	5.48E-06
	3.90E-01	5.10E-03	1.01E-02	5.15E-05
	4.54E-01	5.50E-03	2.90E-03	1.60E-05
	4.65E-01	5.50E-03	7.08E-04	3.89E-06
	5.10E-01	5.80E-03	5.80E-04	3.36E-06
	5.26E-01	5.80E-03	1.70E-03	9.86E-06
	5.34E-01	5.80E-03	6.30E-04	3.65E-06
	7.20E-03	0.00E+00	7.93E-02	0.00E+00
				3.64E-04
^{99}Mo	1.95E-02	0.00E+00	3.45E-02	0.00E+00
	1.60E-01	1.96E-05	7.70E-03	1.51E-07
				1.51E-07
^{95}Nb	1.84E-01	1.00E-04	1.26E-05	1.26E-09
	2.01E-01	1.00E-04	1.62E-06	1.62E-10
	2.04E-01	2.00E-04	2.88E-07	5.76E-11
	2.04E-01	2.00E-04	4.51E-08	9.02E-12
	5.42E-01	5.90E-03	4.44E-07	2.62E-09

	5.59E-01	5.90E-03	5.25E-08	3.10E-10
	5.61E-01	5.90E-03	9.39E-09	5.54E-11
	5.62E-01	5.90E-03	1.49E-09	8.79E-12
	7.46E-01	6.30E-03	1.30E-03	8.00E-06
	7.46E-01	6.30E-03	1.30E-03	8.00E-06
	7.65E-01	6.40E-03	2.55E-05	1.63E-07
	7.66E-01	6.40E-03	4.10E-06	2.62E-08
	1.48E-02	0.00E+00	2.98E-04	0.00E+00
	2.30E-03	0.00E+00	1.40E-03	0.00E+00
				1.62E-05
^{237}Np	5.85E-02	0.00E+00	2.30E-03	0.00E+00
	6.54E-02	0.00E+00	1.41E-01	0.00E+00
	8.11E-02	0.00E+00	2.74E-02	0.00E+00
	8.51E-02	0.00E+00	3.40E-03	0.00E+00
	1.01E-01	0.00E+00	9.31E-04	0.00E+00
	8.76E-02	0.00E+00	1.90E-03	0.00E+00
	5.10E-03	0.00E+00	1.67E-02	0.00E+00
	9.66E-02	0.00E+00	3.90E-03	0.00E+00
	1.12E-01	0.00E+00	9.46E-04	0.00E+00
	2.17E-02	0.00E+00	4.30E-03	0.00E+00
	1.13E-01	0.00E+00	1.10E-03	0.00E+00

	3.07E-02	0.00E+00	2.53E-02	0.00E+00
	1.22E-01	0.00E+00	5.50E-03	0.00E+00
	1.38E-01	0.00E+00	1.30E-03	0.00E+00
	1.42E-01	0.00E+00	4.96E-04	0.00E+00
	3.88E-02	0.00E+00	8.60E-03	0.00E+00
	1.30E-01	0.00E+00	2.60E-03	0.00E+00
	1.46E-01	0.00E+00	6.68E-04	0.00E+00
	8.07E-02	0.00E+00	1.00E-03	0.00E+00
	1.01E-01	0.00E+00	6.15E-04	0.00E+00
	7.08E-02	0.00E+00	1.80E-03	0.00E+00
	9.70E-03	0.00E+00	5.17E-01	0.00E+00
				0.00E+00
^{239}Np	2.16E-02	0.00E+00	8.32E-02	0.00E+00
	3.87E-02	0.00E+00	2.11E-02	0.00E+00
	4.31E-02	0.00E+00	7.40E-03	0.00E+00
	2.63E-02	0.00E+00	1.10E-01	0.00E+00
	4.35E-02	0.00E+00	2.98E-02	0.00E+00
	4.79E-02	0.00E+00	1.04E-02	0.00E+00
	3.42E-02	0.00E+00	5.80E-02	0.00E+00
	5.14E-02	0.00E+00	1.62E-02	0.00E+00
	5.57E-02	0.00E+00	5.70E-03	0.00E+00

	3.42E-02	0.00E+00	1.93E-02	0.00E+00
	4.48E-02	0.00E+00	7.14E-02	0.00E+00
	6.19E-02	0.00E+00	2.00E-02	0.00E+00
	6.63E-02	0.00E+00	7.00E-03	0.00E+00
	8.30E-02	0.00E+00	4.81E-02	0.00E+00
	1.00E-01	0.00E+00	1.27E-02	0.00E+00
	1.05E-01	0.00E+00	4.30E-03	0.00E+00
	8.34E-02	0.00E+00	4.20E-03	0.00E+00
	8.79E-02	0.00E+00	7.63E-02	0.00E+00
	1.87E-01	1.00E-04	1.68E-02	1.68E-06
	2.04E-01	2.00E-04	4.10E-03	8.28E-07
	2.08E-01	4.00E-04	1.50E-03	5.84E-07
	1.05E-01	0.00E+00	5.30E-03	0.00E+00
	1.06E-01	0.00E+00	2.02E-01	0.00E+00
	2.05E-01	3.00E-04	4.24E-02	1.27E-05
	2.22E-01	9.00E-04	1.04E-02	9.36E-06
	2.27E-01	1.10E-03	3.70E-03	4.04E-06
	1.56E-01	0.00E+00	1.62E-01	0.00E+00
	2.55E-01	2.10E-03	3.31E-02	6.95E-05
	2.72E-01	2.80E-03	8.10E-03	2.25E-05
	2.76E-01	2.90E-03	2.80E-03	8.24E-06

	7.60E-02	0.00E+00	1.30E-02	0.00E+00
	1.03E-02	0.00E+00	4.10E-01	0.00E+00
				1.29E-04
^{147}Pm	2.92E-02	0.00E+00	3.40E-10	0.00E+00
	6.83E-02	0.00E+00	1.47E-10	0.00E+00
	7.44E-02	0.00E+00	3.37E-11	0.00E+00
	7.57E-02	0.00E+00	8.41E-12	0.00E+00
	7.44E-02	0.00E+00	2.32E-05	0.00E+00
	1.14E-01	0.00E+00	4.08E-06	0.00E+00
	1.20E-01	0.00E+00	8.89E-07	0.00E+00
	1.21E-01	0.00E+00	2.31E-07	0.00E+00
	1.51E-01	1.96E-06	5.35E-10	1.05E-15
	1.90E-01	7.83E-05	1.65E-10	1.29E-14
	1.96E-01	9.01E-05	3.73E-11	3.36E-15
	1.97E-01	9.20E-05	9.37E-12	8.62E-16
	3.26E-02	0.00E+00	1.71E-06	0.00E+00
	4.50E-03	0.00E+00	2.02E-05	0.00E+00
				1.82E-14
^{238}Pu	2.17E-02	0.00E+00	2.04E-01	0.00E+00
	3.80E-02	0.00E+00	5.63E-02	0.00E+00
	4.21E-02	0.00E+00	1.93E-02	0.00E+00

	7.81E-02	0.00E+00	7.12E-04	0.00E+00
	9.43E-02	0.00E+00	1.98E-04	0.00E+00
	9.90E-03	0.00E+00	1.02E-01	0.00E+00
				0.00E+00
^{239}Pu	1.69E-02	0.00E+00	2.29E-02	0.00E+00
	3.31E-02	0.00E+00	6.20E-03	0.00E+00
	3.72E-02	0.00E+00	2.10E-03	0.00E+00
	2.99E-02	0.00E+00	6.15E-02	0.00E+00
	4.61E-02	0.00E+00	1.70E-02	0.00E+00
	5.02E-02	0.00E+00	5.90E-03	0.00E+00
	3.51E-02	0.00E+00	2.80E-04	0.00E+00
	4.69E-02	0.00E+00	2.06E-04	0.00E+00
	7.70E-02	0.00E+00	1.51E-04	0.00E+00
	9.90E-03	0.00E+00	4.29E-02	0.00E+00
				0.00E+00
^{226}Ra	8.78E-02	0.00E+00	7.00E-03	0.00E+00
	1.68E-01	0.00E+00	1.34E-02	0.00E+00
	1.82E-01	1.00E-04	3.60E-03	3.56E-07
	1.85E-01	1.00E-04	1.20E-03	1.24E-07
	1.64E-01	0.00E+00	4.64E-06	0.00E+00
	2.44E-01	1.70E-03	4.40E-06	7.48E-09

	2.58E-01	2.30E-03	1.16E-06	2.67E-09
	2.61E-01	2.40E-03	4.03E-07	9.67E-10
	6.27E-02	0.00E+00	2.29E-04	0.00E+00
	8.70E-03	0.00E+00	1.09E-02	0.00E+00
				4.91E-07
^{103}Ru	1.65E-02	0.00E+00	9.89E-02	0.00E+00
	3.64E-02	0.00E+00	7.33E-01	0.00E+00
	3.91E-02	0.00E+00	1.45E-01	0.00E+00
	3.01E-02	0.00E+00	7.70E-03	0.00E+00
	4.74E-01	5.60E-03	4.40E-03	2.45E-05
	4.94E-01	5.70E-03	4.91E-04	2.80E-06
	1.70E-02	0.00E+00	2.12E-02	0.00E+00
	2.40E-03	0.00E+00	8.03E-01	0.00E+00
				2.73E-05
^{127}Sb	2.93E-02	0.00E+00	1.42E-02	0.00E+00
	4.41E-01	5.40E-03	2.40E-03	1.30E-05
				1.30E-05
^{75}Se	1.25E-02	0.00E+00	4.19E-02	0.00E+00
	2.29E-02	0.00E+00	8.40E-03	0.00E+00
	2.42E-02	0.00E+00	1.30E-03	0.00E+00
	5.42E-02	0.00E+00	2.90E-03	0.00E+00

	6.45E-02	0.00E+00	3.29E-04	0.00E+00
	8.49E-02	0.00E+00	2.66E-02	0.00E+00
	9.52E-02	0.00E+00	3.60E-03	0.00E+00
	9.65E-02	0.00E+00	5.43E-04	0.00E+00
	1.09E-01	0.00E+00	6.40E-03	0.00E+00
	1.20E-01	0.00E+00	6.68E-04	0.00E+00
	1.24E-01	0.00E+00	1.54E-02	0.00E+00
	1.35E-01	0.00E+00	1.60E-03	0.00E+00
	1.36E-01	0.00E+00	2.43E-04	0.00E+00
	1.87E-01	1.00E-04	2.75E-04	2.75E-08
	2.53E-01	2.10E-03	3.80E-03	7.90E-06
	2.63E-01	2.40E-03	3.98E-04	9.55E-07
	2.65E-01	2.50E-03	6.07E-05	1.52E-07
	2.68E-01	2.60E-03	1.90E-03	4.89E-06
	2.78E-01	3.00E-03	2.02E-04	6.06E-07
	2.92E-01	3.50E-03	6.17E-04	2.16E-06
	3.02E-01	3.80E-03	7.78E-05	2.96E-07
	3.89E-01	5.00E-03	1.37E-04	6.85E-07
	9.10E-03	0.00E+00	4.15E-01	0.00E+00
	1.20E-03	0.00E+00	1.30E+00	0.00E+00
				1.77E-05

^{89}Sr	8.92E-01	6.60E-03	7.10E-07	4.69E-09
	9.07E-01	6.60E-03	8.66E-08	5.72E-10
	9.09E-01	6.60E-03	1.49E-08	9.83E-11
	9.09E-01	6.60E-03	2.12E-09	1.40E-11
	1.27E-02	0.00E+00	2.01E-07	0.00E+00
	1.90E-03	0.00E+00	8.30E-07	0.00E+00
				5.37E-09
^{129m}Te	7.37E-02	0.00E+00	2.00E-01	0.00E+00
	1.01E-01	0.00E+00	1.52E-01	0.00E+00
	1.05E-01	0.00E+00	3.55E-02	0.00E+00
	1.05E-01	0.00E+00	7.50E-03	0.00E+00
	2.27E-02	0.00E+00	3.96E-02	0.00E+00
	3.20E-03	0.00E+00	4.88E-01	0.00E+00
				0.00E+00
^{131m}Te	1.50E-01	0.00E+00	1.68E-01	0.00E+00
	1.77E-01	1.00E-04	6.35E-02	6.35E-06
	1.81E-01	1.00E-04	1.40E-02	1.40E-06
	1.82E-01	1.00E-04	3.60E-03	3.55E-07
	2.27E-02	0.00E+00	2.09E-02	0.00E+00
	3.20E-03	0.00E+00	1.99E-01	0.00E+00
	4.80E-02	0.00E+00	4.90E-02	0.00E+00

	7.60E-02	0.00E+00	6.00E-03	0.00E+00
	6.89E-02	0.00E+00	4.44E-02	0.00E+00
	9.69E-02	0.00E+00	6.10E-03	0.00E+00
	1.17E-01	0.00E+00	1.03E-02	0.00E+00
	1.45E-01	0.00E+00	1.30E-03	0.00E+00
	1.68E-01	0.00E+00	1.90E-03	0.00E+00
	2.08E-01	4.00E-04	1.30E-03	5.28E-07
	3.01E-01	3.80E-03	2.40E-03	9.12E-06
	7.41E-01	6.30E-03	6.63E-04	4.18E-06
	8.19E-01	6.50E-03	4.38E-04	2.85E-06
	2.36E-02	0.00E+00	1.31E-02	0.00E+00
	3.30E-03	0.00E+00	1.05E-01	0.00E+00
				2.48E-05
^{132}Te	1.66E-02	0.00E+00	7.33E-01	0.00E+00
	4.45E-02	0.00E+00	9.65E-02	0.00E+00
	4.87E-02	0.00E+00	1.93E-02	0.00E+00
	7.86E-02	0.00E+00	9.90E-03	0.00E+00
	8.31E-02	0.00E+00	9.60E-03	0.00E+00
	1.11E-01	0.00E+00	2.00E-03	0.00E+00
	1.15E-01	0.00E+00	4.12E-04	0.00E+00
	1.16E-01	0.00E+00	9.81E-05	0.00E+00

	1.95E-01	8.81E-05	7.10E-02	6.26E-06
	2.36E-02	0.00E+00	9.69E-02	0.00E+00
	3.30E-03	0.00E+00	7.69E-01	0.00E+00
				6.26E-06
^{170}Tm	2.12E-02	0.00E+00	6.14E-05	0.00E+00
	6.90E-02	0.00E+00	1.53E-04	0.00E+00
	7.65E-02	0.00E+00	3.71E-05	0.00E+00
	7.83E-02	0.00E+00	1.02E-05	0.00E+00
	3.97E-02	0.00E+00	6.22E-05	0.00E+00
	5.50E-03	0.00E+00	1.00E-03	0.00E+00
	2.29E-02	0.00E+00	3.57E-02	0.00E+00
	7.38E-02	0.00E+00	9.31E-02	0.00E+00
	8.19E-02	0.00E+00	2.28E-02	0.00E+00
	8.38E-02	0.00E+00	6.30E-03	0.00E+00
	4.22E-02	0.00E+00	1.90E-03	0.00E+00
	5.80E-03	0.00E+00	9.36E-02	0.00E+00
				0.00E+00
^{91}Y	1.19E+00	7.00E-03	1.02E-06	7.14E-09
	1.20E+00	7.00E-03	1.12E-07	7.84E-10
	1.20E+00	7.00E-03	1.94E-08	1.36E-10
	1.21E+00	7.00E-03	2.52E-08	1.76E-10

	1.34E-02	0.00E+00	2.71E-07	0.00E+00
	2.00E-03	0.00E+00	1.16E-06	0.00E+00
				8.24E-09
^{169}Yb	6.10E-03	0.00E+00	2.69E-01	0.00E+00
	7.90E-03	0.00E+00	7.05E-02	0.00E+00
	1.06E-02	0.00E+00	3.04E-02	0.00E+00
	1.85E-02	0.00E+00	6.80E-03	0.00E+00
	3.70E-03	0.00E+00	3.89E-01	0.00E+00
	5.30E-02	0.00E+00	7.03E-02	0.00E+00
	6.08E-02	0.00E+00	1.57E-02	0.00E+00
	6.27E-02	0.00E+00	4.10E-03	0.00E+00
	3.42E-02	0.00E+00	7.92E-02	0.00E+00
	8.35E-02	0.00E+00	1.36E-02	0.00E+00
	9.13E-02	0.00E+00	3.10E-03	0.00E+00
	5.04E-02	0.00E+00	3.43E-01	0.00E+00
	9.97E-02	0.00E+00	5.46E-02	0.00E+00
	1.08E-01	0.00E+00	1.22E-02	0.00E+00
	1.09E-01	0.00E+00	3.30E-03	0.00E+00
	5.88E-02	0.00E+00	1.31E-02	0.00E+00
	1.08E-01	0.00E+00	1.35E-02	0.00E+00
	1.16E-01	0.00E+00	3.30E-03	0.00E+00

	7.11E-02	0.00E+00	6.16E-02	0.00E+00
	1.20E-01	0.00E+00	5.26E-02	0.00E+00
	1.28E-01	0.00E+00	1.28E-02	0.00E+00
	1.30E-01	0.00E+00	3.30E-03	0.00E+00
	1.18E-01	0.00E+00	1.09E-01	0.00E+00
	1.67E-01	0.00E+00	1.80E-02	0.00E+00
	1.75E-01	0.00E+00	4.10E-03	0.00E+00
	1.77E-01	1.00E-04	1.10E-03	1.09E-07
	1.39E-01	0.00E+00	1.29E-01	0.00E+00
	1.88E-01	1.00E-04	2.11E-02	2.11E-06
	1.96E-01	1.00E-04	4.70E-03	4.74E-07
	1.98E-01	1.00E-04	1.30E-03	1.27E-07
	2.48E-01	1.90E-03	4.80E-03	9.18E-06
	2.98E-01	3.70E-03	1.40E-03	5.18E-06
	4.09E-02	0.00E+00	1.05E-01	0.00E+00
	5.70E-03	0.00E+00	1.62E+00	0.00E+00
				1.72E-05
^{95}Zr	2.17E-01	7.00E-04	6.00E-03	4.18E-06
	2.33E-01	1.30E-03	1.20E-03	1.55E-06
	2.35E-01	1.40E-03	2.19E-04	3.07E-07
	7.05E-01	6.30E-03	5.84E-04	3.68E-06

	7.22E-01	6.30E-03	6.51E-05	4.10E-07
	7.38E-01	6.30E-03	7.89E-04	4.97E-06
	7.54E-01	6.40E-03	7.23E-05	4.63E-07
	1.40E-02	0.00E+00	1.80E-03	0.00E+00
	2.20E-03	0.00E+00	8.70E-03	0.00E+00
				1.56E-05

APPENDIX D ELECTRON DOSE RATE CONVERSION FACTORS

Radionuclide	Energy Bin (MeV)			Energy (MeV) Average	#/beta transition	Dose Conversion factor
^{140}Ba						
	0.00E+00	-	5.03E-02	2.52E-02	1.22E-01	0.00E+00
	5.03E-02	-	1.01E-01	7.54E-02	1.17E-01	0.00E+00
	1.01E-01	-	1.51E-01	1.26E-01	1.10E-01	0.00E+00
	1.51E-01	-	2.01E-01	1.76E-01	1.02E-01	1.00E-04
	2.01E-01	-	2.51E-01	2.26E-01	9.08E-02	1.10E-03
	2.51E-01	-	3.02E-01	2.76E-01	7.91E-02	2.90E-03
	3.02E-01	-	3.52E-01	3.27E-01	6.73E-02	4.20E-03
	3.52E-01	-	4.02E-01	3.77E-01	5.64E-02	4.90E-03
	4.02E-01	-	4.52E-01	4.27E-01	4.79E-02	5.30E-03
	4.52E-01	-	5.03E-01	4.77E-01	4.19E-02	5.60E-03
	5.03E-01	-	5.53E-01	5.28E-01	3.71E-02	5.80E-03
	5.53E-01	-	6.03E-01	5.78E-01	3.24E-02	6.00E-03
	6.03E-01	-	6.53E-01	6.28E-01	2.78E-02	6.10E-03
	6.53E-01	-	7.04E-01	6.78E-01	2.28E-02	6.20E-03
	7.04E-01	-	7.54E-01	7.29E-01	1.78E-02	6.30E-03
	7.54E-01	-	8.04E-01	7.79E-01	1.29E-02	6.40E-03

	8.04E-01	-	8.54E-01	8.29E-01	8.40E-03	6.50E-03
	8.54E-01	-	9.05E-01	8.79E-01	4.50E-03	6.60E-03
	9.05E-01	-	9.55E-01	9.30E-01	1.90E-03	6.60E-03
	9.55E-01	-	1.01E+00	9.80E-01	2.95E-04	6.70E-03
						8.73E-02
^{144}Ce						
	0.00E+00	-	1.58E-02	7.90E-03	1.35E-01	0.00E+00
	1.58E-02	-	3.15E-02	2.37E-02	1.24E-01	0.00E+00
	3.15E-02	-	4.73E-02	3.94E-02	1.13E-01	0.00E+00
	4.73E-02	-	6.31E-02	5.52E-02	1.02E-01	0.00E+00
	6.31E-02	-	7.89E-02	7.10E-02	9.11E-02	0.00E+00
	7.89E-02	-	9.46E-02	8.68E-02	8.03E-02	0.00E+00
	9.46E-02	-	1.10E-01	1.03E-01	6.98E-02	0.00E+00
	1.10E-01	-	1.26E-01	1.18E-01	5.97E-02	0.00E+00
	1.26E-01	-	1.42E-01	1.34E-01	5.03E-02	0.00E+00
	1.42E-01	-	1.58E-01	1.50E-01	4.17E-02	0.00E+00
	1.58E-01	-	1.74E-01	1.66E-01	3.42E-02	0.00E+00
	1.74E-01	-	1.89E-01	1.81E-01	2.78E-02	1.00E-04
	1.89E-01	-	2.05E-01	1.97E-01	2.23E-02	1.00E-04
	2.05E-01	-	2.21E-01	2.13E-01	1.73E-02	6.00E-04
	2.21E-01	-	2.37E-01	2.29E-01	1.28E-02	1.20E-03

	2.37E-01	-	2.52E-01	2.44E-01	8.90E-03	1.70E-03
	2.52E-01	-	2.68E-01	2.60E-01	5.60E-03	2.30E-03
	2.68E-01	-	2.84E-01	2.76E-01	3.00E-03	2.90E-03
	2.84E-01	-	3.00E-01	2.92E-01	1.10E-03	3.50E-03
	3.00E-01	-	3.15E-01	3.08E-01	1.89E-04	3.90E-03
						1.63E-02
^{60}Co						
	0.00E+00	-	7.46E-02	3.73E-02	4.45E-01	0.00E+00
	7.46E-02	-	1.49E-01	1.12E-01	3.30E-01	0.00E+00
	1.49E-01	-	2.24E-01	1.86E-01	1.78E-01	1.00E-04
	2.24E-01	-	2.98E-01	2.61E-01	4.58E-02	2.40E-03
	2.98E-01	-	3.73E-01	3.36E-01	6.36E-04	4.30E-03
	3.73E-01	-	4.47E-01	4.10E-01	5.99E-05	5.30E-03
	4.47E-01	-	5.22E-01	4.85E-01	5.96E-05	5.60E-03
	5.22E-01	-	5.96E-01	5.59E-01	5.77E-05	5.90E-03
	5.96E-01	-	6.71E-01	6.34E-01	5.54E-05	6.10E-03
	6.71E-01	-	7.46E-01	7.08E-01	5.40E-05	6.30E-03
	7.46E-01	-	8.20E-01	7.83E-01	5.23E-05	6.40E-03
	8.20E-01	-	8.95E-01	8.57E-01	4.99E-05	6.50E-03
	8.95E-01	-	9.69E-01	9.32E-01	4.66E-05	6.60E-03
	9.69E-01	-	1.04E+00	1.01E+00	4.24E-05	6.80E-03

	1.04E+00	-	1.12E+00	1.08E+00	3.71E-05	6.80E-03
	1.12E+00	-	1.19E+00	1.16E+00	3.06E-05	6.90E-03
	1.19E+00	-	1.27E+00	1.23E+00	2.31E-05	7.00E-03
	1.27E+00	-	1.34E+00	1.30E+00	1.47E-05	7.10E-03
	1.34E+00	-	1.42E+00	1.38E+00	6.66E-06	7.20E-03
	1.42E+00	-	1.49E+00	1.45E+00	1.57E-06	7.30E-03
						1.05E-01
^{134}Cs						
	0.00E+00	-	7.27E-02	3.64E-02	3.95E-01	0.00E+00
	7.27E-02	-	1.45E-01	1.09E-01	1.49E-01	0.00E+00
	1.45E-01	-	2.18E-01	1.82E-01	1.34E-01	1.00E-04
	2.18E-01	-	2.91E-01	2.55E-01	1.14E-01	2.10E-03
	2.91E-01	-	3.64E-01	3.27E-01	8.95E-02	4.20E-03
	3.64E-01	-	4.36E-01	4.00E-01	6.30E-02	5.20E-03
	4.36E-01	-	5.09E-01	4.73E-01	3.76E-02	5.60E-03
	5.09E-01	-	5.82E-01	5.45E-01	1.61E-02	5.90E-03
	5.82E-01	-	6.54E-01	6.18E-01	2.80E-03	6.10E-03
	6.54E-01	-	7.27E-01	6.91E-01	4.03E-05	6.20E-03
	7.27E-01	-	8.00E-01	7.63E-01	1.44E-05	6.40E-03
	8.00E-01	-	8.72E-01	8.36E-01	6.92E-06	6.50E-03
	8.72E-01	-	9.45E-01	9.09E-01	4.09E-06	6.60E-03

	9.45E-01	-	1.02E+00	9.81E-01	3.52E-06	6.70E-03
	1.02E+00	-	1.09E+00	1.05E+00	2.96E-06	6.80E-03
	1.09E+00	-	1.16E+00	1.13E+00	2.31E-06	6.90E-03
	1.16E+00	-	1.24E+00	1.20E+00	1.64E-06	7.00E-03
	1.24E+00	-	1.31E+00	1.27E+00	9.74E-07	7.10E-03
	1.31E+00	-	1.38E+00	1.34E+00	4.16E-07	7.10E-03
	1.38E+00	-	1.45E+00	1.42E+00	7.16E-08	7.20E-03
						1.04E-01
^{136}Cs						
	0.00E+00	-	3.40E-02	1.70E-02	2.17E-01	0.00E+00
	3.40E-02	-	6.81E-02	5.11E-02	1.91E-01	0.00E+00
	6.81E-02	-	1.02E-01	8.51E-02	1.64E-01	0.00E+00
	1.02E-01	-	1.36E-01	1.19E-01	1.35E-01	0.00E+00
	1.36E-01	-	1.70E-01	1.53E-01	1.06E-01	0.00E+00
	1.70E-01	-	2.04E-01	1.87E-01	7.84E-02	1.00E-04
	2.04E-01	-	2.38E-01	2.21E-01	5.29E-02	9.00E-04
	2.38E-01	-	2.72E-01	2.55E-01	3.08E-02	2.20E-03
	2.72E-01	-	3.06E-01	2.89E-01	1.38E-02	3.40E-03
	3.06E-01	-	3.41E-01	3.24E-01	4.40E-03	4.10E-03
	3.41E-01	-	3.75E-01	3.58E-01	2.10E-03	4.60E-03
	3.75E-01	-	4.09E-01	3.92E-01	1.60E-03	5.10E-03

	4.09E-01	-	4.43E-01	4.26E-01	1.10E-03	5.30E-03
	4.43E-01	-	4.77E-01	4.60E-01	7.70E-04	5.50E-03
	4.77E-01	-	5.11E-01	4.94E-01	4.83E-04	5.70E-03
	5.11E-01	-	5.45E-01	5.28E-01	3.18E-04	5.80E-03
	5.45E-01	-	5.79E-01	5.62E-01	2.04E-04	5.90E-03
	5.79E-01	-	6.13E-01	5.96E-01	1.11E-04	6.00E-03
	6.13E-01	-	6.47E-01	6.30E-01	4.26E-05	6.10E-03
	6.47E-01	-	6.81E-01	6.64E-01	7.15E-06	6.20E-03
						6.69E-02
^{137}Cs						
	0.00E+00	-	5.87E-02	2.94E-02	1.93E-01	0.00E+00
	5.87E-02	-	1.17E-01	8.80E-02	1.76E-01	0.00E+00
	1.17E-01	-	1.76E-01	1.47E-01	1.61E-01	0.00E+00
	1.76E-01	-	2.35E-01	2.05E-01	1.44E-01	3.00E-04
	2.35E-01	-	2.93E-01	2.64E-01	1.22E-01	2.50E-03
	2.93E-01	-	3.52E-01	3.23E-01	9.38E-02	4.10E-03
	3.52E-01	-	4.11E-01	3.81E-01	6.01E-02	4.90E-03
	4.11E-01	-	4.69E-01	4.40E-01	2.64E-02	5.40E-03
	4.69E-01	-	5.28E-01	4.99E-01	5.70E-03	5.70E-03
	5.28E-01	-	5.87E-01	5.57E-01	3.30E-03	5.90E-03
	5.87E-01	-	6.45E-01	6.16E-01	3.10E-03	6.10E-03

	6.45E-01	-	7.04E-01	6.75E-01	2.80E-03	6.20E-03
	7.04E-01	-	7.63E-01	7.33E-01	2.50E-03	6.30E-03
	7.63E-01	-	8.21E-01	7.92E-01	2.20E-03	6.40E-03
	8.21E-01	-	8.80E-01	8.51E-01	1.80E-03	6.50E-03
	8.80E-01	-	9.39E-01	9.09E-01	1.40E-03	6.60E-03
	9.39E-01	-	9.97E-01	9.68E-01	9.92E-04	6.70E-03
	9.97E-01	-	1.06E+00	1.03E+00	5.91E-04	6.80E-03
	1.06E+00	-	1.11E+00	1.09E+00	2.45E-04	6.80E-03
	1.11E+00	-	1.17E+00	1.14E+00	5.38E-05	6.90E-03
						9.41E-02
^{129}I						
	0.00E+00	-	7.50E-03	3.80E-03	9.39E-02	0.00E+00
	7.50E-03	-	1.50E-02	1.13E-02	8.58E-02	0.00E+00
	1.50E-02	-	2.26E-02	1.88E-02	8.47E-02	0.00E+00
	2.26E-02	-	3.01E-02	2.64E-02	8.30E-02	0.00E+00
	3.01E-02	-	3.76E-02	3.39E-02	8.06E-02	0.00E+00
	3.76E-02	-	4.51E-02	4.14E-02	7.75E-02	0.00E+00
	4.51E-02	-	5.26E-02	4.89E-02	7.37E-02	0.00E+00
	5.26E-02	-	6.02E-02	5.64E-02	6.92E-02	0.00E+00
	6.02E-02	-	6.77E-02	6.39E-02	6.40E-02	0.00E+00
	6.77E-02	-	7.52E-02	7.15E-02	5.83E-02	0.00E+00

	7.52E-02	-	8.27E-02	7.89E-02	5.20E-02	0.00E+00
	8.27E-02	-	9.03E-02	8.65E-02	4.53E-02	0.00E+00
	9.03E-02	-	9.78E-02	9.41E-02	3.83E-02	0.00E+00
	9.78E-02	-	1.05E-01	1.02E-01	3.12E-02	0.00E+00
	1.05E-01	-	1.13E-01	1.09E-01	2.42E-02	0.00E+00
	1.13E-01	-	1.20E-01	1.17E-01	1.76E-02	0.00E+00
	1.20E-01	-	1.28E-01	1.24E-01	1.15E-02	0.00E+00
	1.28E-01	-	1.35E-01	1.32E-01	6.30E-03	0.00E+00
	1.35E-01	-	1.43E-01	1.39E-01	2.50E-03	0.00E+00
	1.43E-01	-	1.50E-01	1.47E-01	4.40E-04	0.00E+00
^{131}I						
	0.00E+00	-	4.03E-02	2.02E-02	1.38E-01	0.00E+00
	4.03E-02	-	8.07E-02	6.05E-02	1.31E-01	0.00E+00
	8.07E-02	-	1.21E-01	1.01E-01	1.23E-01	0.00E+00
	1.21E-01	-	1.61E-01	1.41E-01	1.13E-01	0.00E+00
	1.61E-01	-	2.02E-01	1.82E-01	1.02E-01	1.00E-04
	2.02E-01	-	2.42E-01	2.22E-01	8.94E-02	9.00E-04
	2.42E-01	-	2.82E-01	2.62E-01	7.70E-02	2.40E-03
	2.82E-01	-	3.23E-01	3.03E-01	6.48E-02	3.80E-03
	3.23E-01	-	3.63E-01	3.43E-01	5.30E-02	4.40E-03

	3.63E-01	-	4.03E-01	3.83E-01	4.15E-02	5.00E-03
	4.03E-01	-	4.44E-01	4.24E-01	3.03E-02	5.30E-03
	4.44E-01	-	4.84E-01	4.64E-01	2.00E-02	5.50E-03
	4.84E-01	-	5.25E-01	5.04E-01	1.12E-02	5.70E-03
	5.25E-01	-	5.65E-01	5.45E-01	4.50E-03	5.90E-03
	5.65E-01	-	6.05E-01	5.85E-01	8.56E-04	6.00E-03
	6.05E-01	-	6.46E-01	6.25E-01	1.15E-04	6.10E-03
	6.46E-01	-	6.86E-01	6.66E-01	6.95E-05	6.20E-03
	6.86E-01	-	7.26E-01	7.06E-01	4.13E-05	6.30E-03
	7.26E-01	-	7.67E-01	7.46E-01	1.73E-05	6.30E-03
	7.67E-01	-	8.07E-01	7.87E-01	2.96E-06	6.40E-03
						7.63E-02
^{132}I						
	0.00E+00	-	1.07E-01	5.35E-02	1.30E-01	0.00E+00
	1.07E-01	-	2.14E-01	1.61E-01	1.35E-01	0.00E+00
	2.14E-01	-	3.21E-01	2.68E-01	1.33E-01	2.60E-03
	3.21E-01	-	4.28E-01	3.75E-01	1.23E-01	4.80E-03
	4.28E-01	-	5.35E-01	4.81E-01	1.08E-01	5.60E-03
	5.35E-01	-	6.42E-01	5.88E-01	8.91E-02	6.00E-03
	6.42E-01	-	7.49E-01	6.95E-01	7.10E-02	6.20E-03
	7.49E-01	-	8.56E-01	8.02E-01	5.61E-02	6.50E-03

	8.56E-01	-	9.63E-01	9.09E-01	4.31E-02	6.60E-03
	9.63E-01	-	1.07E+00	1.02E+00	3.25E-02	6.80E-03
	1.07E+00	-	1.18E+00	1.12E+00	2.41E-02	6.90E-03
	1.18E+00	-	1.28E+00	1.23E+00	1.78E-02	7.00E-03
	1.28E+00	-	1.39E+00	1.34E+00	1.29E-02	7.10E-03
	1.39E+00	-	1.50E+00	1.44E+00	9.10E-03	7.30E-03
	1.50E+00	-	1.60E+00	1.55E+00	6.40E-03	7.40E-03
	1.60E+00	-	1.71E+00	1.66E+00	4.50E-03	7.50E-03
	1.71E+00	-	1.82E+00	1.77E+00	3.00E-03	7.60E-03
	1.82E+00	-	1.93E+00	1.87E+00	1.70E-03	7.70E-03
	1.93E+00	-	2.03E+00	1.98E+00	6.54E-04	7.80E-03
	2.03E+00	-	2.14E+00	2.09E+00	1.33E-04	7.90E-03
						1.19E-01
^{133}I						
	0.00E+00	-	7.63E-02	3.82E-02	1.05E-01	0.00E+00
	7.63E-02	-	1.53E-01	1.15E-01	1.06E-01	0.00E+00
	1.53E-01	-	2.29E-01	1.91E-01	1.05E-01	1.00E-04
	2.29E-01	-	3.05E-01	2.67E-01	1.01E-01	2.60E-03
	3.05E-01	-	3.82E-01	3.44E-01	9.57E-02	4.40E-03
	3.82E-01	-	4.58E-01	4.20E-01	8.94E-02	5.30E-03
	4.58E-01	-	5.34E-01	4.96E-01	8.28E-02	5.70E-03

	5.34E-01	-	6.11E-01	5.73E-01	7.51E-02	6.00E-03
	6.11E-01	-	6.87E-01	6.49E-01	6.58E-02	6.10E-03
	6.87E-01	-	7.63E-01	7.25E-01	5.52E-02	6.30E-03
	7.63E-01	-	8.40E-01	8.02E-01	4.39E-02	6.50E-03
	8.40E-01	-	9.16E-01	8.78E-01	3.27E-02	6.60E-03
	9.16E-01	-	9.92E-01	9.54E-01	2.22E-02	6.70E-03
	9.92E-01	-	1.07E+00	1.03E+00	1.29E-02	6.80E-03
	1.07E+00	-	1.15E+00	1.11E+00	5.70E-03	6.90E-03
	1.15E+00	-	1.22E+00	1.18E+00	1.20E-03	7.00E-03
	1.22E+00	-	1.30E+00	1.26E+00	2.91E-04	7.10E-03
	1.30E+00	-	1.37E+00	1.34E+00	1.23E-04	7.10E-03
	1.37E+00	-	1.45E+00	1.41E+00	5.54E-05	7.20E-03
	1.45E+00	-	1.53E+00	1.49E+00	9.02E-06	7.30E-03
						1.06E-01
^{134}I						
	0.00E+00	-	1.21E-01	6.05E-02	8.91E-02	0.00E+00
	1.21E-01	-	2.42E-01	1.81E-01	1.05E-01	1.00E-04
	2.42E-01	-	3.63E-01	3.02E-01	1.15E-01	3.80E-03
	3.63E-01	-	4.84E-01	4.23E-01	1.18E-01	5.30E-03
	4.84E-01	-	6.05E-01	5.44E-01	1.15E-01	5.90E-03
	6.05E-01	-	7.26E-01	6.65E-01	1.06E-01	6.20E-03

	7.26E-01	-	8.47E-01	7.86E-01	9.26E-02	6.40E-03
	8.47E-01	-	9.68E-01	9.07E-01	7.63E-02	6.60E-03
	9.68E-01	-	1.09E+00	1.03E+00	5.86E-02	6.80E-03
	1.09E+00	-	1.21E+00	1.15E+00	4.19E-02	6.90E-03
	1.21E+00	-	1.33E+00	1.27E+00	2.88E-02	7.10E-03
	1.33E+00	-	1.45E+00	1.39E+00	1.95E-02	7.20E-03
	1.45E+00	-	1.57E+00	1.51E+00	1.27E-02	7.30E-03
	1.57E+00	-	1.69E+00	1.63E+00	8.40E-03	7.50E-03
	1.69E+00	-	1.81E+00	1.75E+00	5.60E-03	7.60E-03
	1.81E+00	-	1.94E+00	1.87E+00	3.70E-03	7.70E-03
	1.94E+00	-	2.06E+00	2.00E+00	2.40E-03	7.80E-03
	2.06E+00	-	2.18E+00	2.12E+00	1.20E-03	7.90E-03
	2.18E+00	-	2.30E+00	2.24E+00	4.83E-04	8.00E-03
	2.30E+00	-	2.42E+00	2.36E+00	7.66E-05	8.10E-03
						1.24E-01
^{135}I						
	0.00E+00	-	1.09E-01	5.46E-02	1.98E-01	0.00E+00
	1.09E-01	-	2.18E-01	1.64E-01	1.81E-01	0.00E+00
	2.18E-01	-	3.28E-01	2.73E-01	1.53E-01	2.80E-03
	3.28E-01	-	4.37E-01	3.82E-01	1.25E-01	5.00E-03
	4.37E-01	-	5.46E-01	4.92E-01	1.02E-01	5.70E-03

	5.46E-01	-	6.55E-01	6.01E-01	8.11E-02	6.00E-03
	6.55E-01	-	7.65E-01	7.10E-01	6.01E-02	6.30E-03
	7.65E-01	-	8.74E-01	8.19E-01	4.15E-02	6.50E-03
	8.74E-01	-	9.83E-01	9.28E-01	2.62E-02	6.60E-03
	9.83E-01	-	1.09E+00	1.04E+00	1.56E-02	6.80E-03
	1.09E+00	-	1.20E+00	1.15E+00	8.80E-03	6.90E-03
	1.20E+00	-	1.31E+00	1.26E+00	4.20E-03	7.00E-03
	1.31E+00	-	1.42E+00	1.37E+00	1.40E-03	7.20E-03
	1.42E+00	-	1.53E+00	1.47E+00	4.65E-04	7.30E-03
	1.53E+00	-	1.64E+00	1.58E+00	3.22E-04	7.40E-03
	1.64E+00	-	1.75E+00	1.69E+00	2.50E-04	7.50E-03
	1.75E+00	-	1.86E+00	1.80E+00	1.81E-04	7.60E-03
	1.86E+00	-	1.97E+00	1.91E+00	1.08E-04	7.70E-03
	1.97E+00	-	2.08E+00	2.02E+00	4.95E-05	7.80E-03
	2.08E+00	-	2.18E+00	2.13E+00	1.25E-05	7.90E-03
						1.20E-01
^{99}Mo						
	0.00E+00	-	6.07E-02	3.04E-02	9.51E-02	0.00E+00
	6.07E-02	-	1.21E-01	9.10E-02	9.49E-02	0.00E+00
	1.21E-01	-	1.82E-01	1.52E-01	9.22E-02	0.00E+00
	1.82E-01	-	2.43E-01	2.13E-01	8.71E-02	6.00E-04

	2.43E-01	-	3.04E-01	2.73E-01	8.02E-02	2.80E-03
	3.04E-01	-	3.64E-01	3.34E-01	7.29E-02	4.30E-03
	3.64E-01	-	4.25E-01	3.95E-01	6.69E-02	5.10E-03
	4.25E-01	-	4.86E-01	4.55E-01	6.36E-02	5.50E-03
	4.86E-01	-	5.46E-01	5.16E-01	6.05E-02	5.80E-03
	5.46E-01	-	6.07E-01	5.77E-01	5.63E-02	6.00E-03
	6.07E-01	-	6.68E-01	6.37E-01	5.11E-02	6.10E-03
	6.68E-01	-	7.28E-01	6.98E-01	4.51E-02	6.20E-03
	7.28E-01	-	7.89E-01	7.59E-01	3.85E-02	6.40E-03
	7.89E-01	-	8.50E-01	8.20E-01	3.16E-02	6.50E-03
	8.50E-01	-	9.11E-01	8.80E-01	2.47E-02	6.60E-03
	9.11E-01	-	9.71E-01	9.41E-01	1.79E-02	6.70E-03
	9.71E-01	-	1.03E+00	1.00E+00	1.18E-02	6.80E-03
	1.03E+00	-	1.09E+00	1.06E+00	6.40E-03	6.80E-03
	1.09E+00	-	1.15E+00	1.12E+00	2.70E-03	6.90E-03
	1.15E+00	-	1.21E+00	1.18E+00	4.11E-04	7.00E-03
						9.61E-02
^{95}Nb						
	0.00E+00	-	8.00E-03	4.00E-03	1.26E-01	0.00E+00
	8.00E-03	-	1.60E-02	1.20E-02	1.16E-01	0.00E+00
	1.60E-02	-	2.40E-02	2.00E-02	1.07E-01	0.00E+00

	2.40E-02	-	3.19E-02	2.80E-02	9.73E-02	0.00E+00
	3.19E-02	-	3.99E-02	3.59E-02	8.82E-02	0.00E+00
	3.99E-02	-	4.79E-02	4.39E-02	7.94E-02	0.00E+00
	4.79E-02	-	5.59E-02	5.19E-02	7.08E-02	0.00E+00
	5.59E-02	-	6.39E-02	5.99E-02	6.24E-02	0.00E+00
	6.39E-02	-	7.19E-02	6.79E-02	5.43E-02	0.00E+00
	7.19E-02	-	7.98E-02	7.59E-02	4.65E-02	0.00E+00
	7.98E-02	-	8.78E-02	8.38E-02	3.92E-02	0.00E+00
	8.78E-02	-	9.58E-02	9.18E-02	3.22E-02	0.00E+00
	9.58E-02	-	1.04E-01	9.98E-02	2.58E-02	0.00E+00
	1.04E-01	-	1.12E-01	1.08E-01	1.99E-02	0.00E+00
	1.12E-01	-	1.20E-01	1.16E-01	1.46E-02	0.00E+00
	1.20E-01	-	1.28E-01	1.24E-01	1.01E-02	0.00E+00
	1.28E-01	-	1.36E-01	1.32E-01	6.30E-03	0.00E+00
	1.36E-01	-	1.44E-01	1.40E-01	3.30E-03	0.00E+00
	1.44E-01	-	1.52E-01	1.48E-01	1.20E-03	0.00E+00
	1.52E-01	-	1.60E-01	1.56E-01	2.20E-04	1.12E-05
						1.12E-05
^{239}Np						
	0.00E+00	-	3.58E-02	1.79E-02	2.02E-01	0.00E+00
	3.58E-02	-	7.15E-02	5.36E-02	1.79E-01	0.00E+00

	7.15E-02	-	1.07E-01	8.94E-02	1.55E-01	0.00E+00
	1.07E-01	-	1.43E-01	1.25E-01	1.29E-01	0.00E+00
	1.43E-01	-	1.79E-01	1.61E-01	1.04E-01	0.00E+00
	1.79E-01	-	2.15E-01	1.97E-01	7.98E-02	1.00E-04
	2.15E-01	-	2.50E-01	2.33E-01	5.80E-02	1.30E-03
	2.50E-01	-	2.86E-01	2.68E-01	3.90E-02	2.60E-03
	2.86E-01	-	3.22E-01	3.04E-01	2.40E-02	3.90E-03
	3.22E-01	-	3.58E-01	3.40E-01	1.38E-02	4.40E-03
	3.58E-01	-	3.93E-01	3.76E-01	7.10E-03	4.90E-03
	3.93E-01	-	4.29E-01	4.11E-01	3.40E-03	5.30E-03
	4.29E-01	-	4.65E-01	4.47E-01	1.90E-03	5.40E-03
	4.65E-01	-	5.01E-01	4.83E-01	1.40E-03	5.60E-03
	5.01E-01	-	5.37E-01	5.19E-01	1.10E-03	5.80E-03
	5.37E-01	-	5.72E-01	5.54E-01	7.15E-04	5.90E-03
	5.72E-01	-	6.08E-01	5.90E-01	4.28E-04	6.00E-03
	6.08E-01	-	6.44E-01	6.26E-01	2.10E-04	6.10E-03
	6.44E-01	-	6.80E-01	6.62E-01	7.47E-05	6.20E-03
	6.80E-01	-	7.15E-01	6.97E-01	1.05E-05	6.20E-03
						6.97E-02
^{147}Pm						
	0.00E+00	-	1.12E-02	5.60E-03	1.22E-01	0.00E+00

	1.12E-02	-	2.25E-02	1.69E-02	1.13E-01	0.00E+00
	2.25E-02	-	3.37E-02	2.81E-02	1.05E-01	0.00E+00
	3.37E-02	-	4.49E-02	3.93E-02	9.65E-02	0.00E+00
	4.49E-02	-	5.62E-02	5.06E-02	8.81E-02	0.00E+00
	5.62E-02	-	6.74E-02	6.18E-02	7.97E-02	0.00E+00
	6.74E-02	-	7.86E-02	7.30E-02	7.14E-02	0.00E+00
	7.86E-02	-	8.99E-02	8.42E-02	6.33E-02	0.00E+00
	8.99E-02	-	1.01E-01	9.55E-02	5.53E-02	0.00E+00
	1.01E-01	-	1.12E-01	1.07E-01	4.76E-02	0.00E+00
	1.12E-01	-	1.24E-01	1.18E-01	4.02E-02	0.00E+00
	1.24E-01	-	1.35E-01	1.29E-01	3.32E-02	0.00E+00
	1.35E-01	-	1.46E-01	1.41E-01	2.67E-02	0.00E+00
	1.46E-01	-	1.57E-01	1.52E-01	2.07E-02	3.33E-06
	1.57E-01	-	1.69E-01	1.63E-01	1.53E-02	2.53E-05
	1.69E-01	-	1.80E-01	1.74E-01	1.05E-02	4.74E-05
	1.80E-01	-	1.91E-01	1.85E-01	6.60E-03	6.93E-05
	1.91E-01	-	2.02E-01	1.97E-01	3.40E-03	9.12E-05
	2.02E-01	-	2.14E-01	2.08E-01	1.40E-03	3.91E-04
	2.14E-01	-	2.25E-01	2.19E-01	1.92E-04	8.07E-04
						1.43E-03
^{106}Ru						

	0.00E+00	-	2.00E-03	1.00E-03	1.39E-01	0.00E+00
	2.00E-03	-	3.90E-03	3.00E-03	1.26E-01	0.00E+00
	3.90E-03	-	5.90E-03	4.90E-03	1.13E-01	0.00E+00
	5.90E-03	-	7.90E-03	6.90E-03	1.01E-01	0.00E+00
	7.90E-03	-	9.80E-03	8.90E-03	8.96E-02	0.00E+00
	9.80E-03	-	1.18E-02	1.08E-02	7.89E-02	0.00E+00
	1.18E-02	-	1.38E-02	1.28E-02	6.89E-02	0.00E+00
	1.38E-02	-	1.58E-02	1.48E-02	5.95E-02	0.00E+00
	1.58E-02	-	1.77E-02	1.68E-02	5.07E-02	0.00E+00
	1.77E-02	-	1.97E-02	1.87E-02	4.25E-02	0.00E+00
	1.97E-02	-	2.17E-02	2.07E-02	3.50E-02	0.00E+00
	2.17E-02	-	2.36E-02	2.27E-02	2.82E-02	0.00E+00
	2.36E-02	-	2.56E-02	2.46E-02	2.21E-02	0.00E+00
	2.56E-02	-	2.76E-02	2.66E-02	1.67E-02	0.00E+00
	2.76E-02	-	2.95E-02	2.86E-02	1.21E-02	0.00E+00
	2.95E-02	-	3.15E-02	3.05E-02	8.10E-03	0.00E+00
	3.15E-02	-	3.35E-02	3.25E-02	5.00E-03	0.00E+00
	3.35E-02	-	3.55E-02	3.45E-02	2.50E-03	0.00E+00
	3.55E-02	-	3.74E-02	3.64E-02	9.93E-04	0.00E+00
	3.74E-02	-	3.94E-02	3.84E-02	1.78E-04	0.00E+00
						0.00E+00

^{127}Sb						
	0.00E+00	-	7.46E-02	3.73E-02	1.40E-01	0.00E+00
	7.46E-02	-	1.49E-01	1.12E-01	1.40E-01	0.00E+00
	1.49E-01	-	2.24E-01	1.87E-01	1.35E-01	1.00E-04
	2.24E-01	-	2.99E-01	2.61E-01	1.26E-01	2.40E-03
	2.99E-01	-	3.73E-01	3.36E-01	1.12E-01	4.30E-03
	3.73E-01	-	4.48E-01	4.11E-01	9.61E-02	5.30E-03
	4.48E-01	-	5.23E-01	4.85E-01	7.92E-02	5.70E-03
	5.23E-01	-	5.97E-01	5.60E-01	6.20E-02	5.90E-03
	5.97E-01	-	6.72E-01	6.34E-01	4.47E-02	6.10E-03
	6.72E-01	-	7.46E-01	7.09E-01	2.91E-02	6.30E-03
	7.46E-01	-	8.21E-01	7.84E-01	1.70E-02	6.40E-03
	8.21E-01	-	8.96E-01	8.58E-01	9.30E-03	6.50E-03
	8.96E-01	-	9.70E-01	9.33E-01	5.10E-03	6.60E-03
	9.70E-01	-	1.04E+00	1.01E+00	2.60E-03	6.80E-03
	1.04E+00	-	1.12E+00	1.08E+00	1.10E-03	6.80E-03
	1.12E+00	-	1.19E+00	1.16E+00	6.24E-04	6.90E-03
	1.19E+00	-	1.27E+00	1.23E+00	4.10E-04	7.00E-03
	1.27E+00	-	1.34E+00	1.31E+00	2.43E-04	7.10E-03
	1.34E+00	-	1.42E+00	1.38E+00	1.02E-04	7.20E-03
	1.42E+00	-	1.49E+00	1.46E+00	2.22E-05	7.30E-03

						1.05E-01
^{129}Sb						
	0.00E+00	-	1.15E-01	5.77E-02	2.25E-01	0.00E+00
	1.15E-01	-	2.31E-01	1.73E-01	2.00E-01	0.00E+00
	2.31E-01	-	3.46E-01	2.89E-01	1.59E-01	3.40E-03
	3.46E-01	-	4.62E-01	4.04E-01	1.13E-01	5.20E-03
	4.62E-01	-	5.77E-01	5.19E-01	7.11E-02	5.80E-03
	5.77E-01	-	6.92E-01	6.35E-01	4.67E-02	6.10E-03
	6.92E-01	-	8.08E-01	7.50E-01	3.87E-02	6.30E-03
	8.08E-01	-	9.23E-01	8.65E-01	3.37E-02	6.50E-03
	9.23E-01	-	1.04E+00	9.81E-01	2.83E-02	6.70E-03
	1.04E+00	-	1.15E+00	1.10E+00	2.30E-02	6.90E-03
	1.15E+00	-	1.27E+00	1.21E+00	1.82E-02	7.00E-03
	1.27E+00	-	1.38E+00	1.33E+00	1.37E-02	7.10E-03
	1.38E+00	-	1.50E+00	1.44E+00	9.90E-03	7.30E-03
	1.50E+00	-	1.62E+00	1.56E+00	6.90E-03	7.40E-03
	1.62E+00	-	1.73E+00	1.67E+00	4.90E-03	7.50E-03
	1.73E+00	-	1.85E+00	1.79E+00	3.50E-03	7.60E-03
	1.85E+00	-	1.96E+00	1.90E+00	2.40E-03	7.70E-03
	1.96E+00	-	2.08E+00	2.02E+00	1.40E-03	7.80E-03
	2.08E+00	-	2.19E+00	2.13E+00	6.02E-04	7.90E-03

	2.19E+00	-	2.31E+00	2.25E+00	1.19E-04	8.00E-03
						1.22E-01
^{89}Sr						
	0.00E+00	-	7.46E-02	3.73E-02	5.56E-02	0.00E+00
	7.46E-02	-	1.49E-01	1.12E-01	6.10E-02	0.00E+00
	1.49E-01	-	2.24E-01	1.87E-01	6.55E-02	1.00E-04
	2.24E-01	-	2.98E-01	2.61E-01	6.84E-02	2.40E-03
	2.98E-01	-	3.73E-01	3.36E-01	7.02E-02	4.30E-03
	3.73E-01	-	4.48E-01	4.10E-01	7.08E-02	5.30E-03
	4.48E-01	-	5.22E-01	4.85E-01	7.06E-02	5.60E-03
	5.22E-01	-	5.97E-01	5.60E-01	6.97E-02	5.90E-03
	5.97E-01	-	6.71E-01	6.34E-01	6.81E-02	6.10E-03
	6.71E-01	-	7.46E-01	7.09E-01	6.57E-02	6.30E-03
	7.46E-01	-	8.21E-01	7.83E-01	6.26E-02	6.40E-03
	8.21E-01	-	8.95E-01	8.58E-01	5.85E-02	6.50E-03
	8.95E-01	-	9.70E-01	9.33E-01	5.33E-02	6.60E-03
	9.70E-01	-	1.04E+00	1.01E+00	4.70E-02	6.80E-03
	1.04E+00	-	1.12E+00	1.08E+00	3.95E-02	6.80E-03
	1.12E+00	-	1.19E+00	1.16E+00	3.11E-02	6.90E-03
	1.19E+00	-	1.27E+00	1.23E+00	2.21E-02	7.00E-03
	1.27E+00	-	1.34E+00	1.31E+00	1.33E-02	7.10E-03

	1.34E+00	-	1.42E+00	1.38E+00	5.60E-03	7.20E-03
	1.42E+00	-	1.49E+00	1.45E+00	1.20E-03	7.30E-03
						1.05E-01
^{90}Sr						
	0.00E+00	-	2.73E-02	1.37E-02	7.79E-02	0.00E+00
	2.73E-02	-	5.46E-02	4.10E-02	7.60E-02	0.00E+00
	5.46E-02	-	8.19E-02	6.83E-02	7.50E-02	0.00E+00
	8.19E-02	-	1.09E-01	9.56E-02	7.40E-02	0.00E+00
	1.09E-01	-	1.37E-01	1.23E-01	7.30E-02	0.00E+00
	1.37E-01	-	1.64E-01	1.50E-01	7.17E-02	0.00E+00
	1.64E-01	-	1.91E-01	1.78E-01	7.01E-02	1.00E-04
	1.91E-01	-	2.18E-01	2.05E-01	6.80E-02	3.00E-04
	2.18E-01	-	2.46E-01	2.32E-01	6.53E-02	1.30E-03
	2.46E-01	-	2.73E-01	2.59E-01	6.19E-02	2.30E-03
	2.73E-01	-	3.00E-01	2.87E-01	5.78E-02	3.30E-03
	3.00E-01	-	3.28E-01	3.14E-01	5.27E-02	4.00E-03
	3.28E-01	-	3.55E-01	3.41E-01	4.68E-02	4.40E-03
	3.55E-01	-	3.82E-01	3.69E-01	4.01E-02	4.80E-03
	3.82E-01	-	4.10E-01	3.96E-01	3.27E-02	5.10E-03
	4.10E-01	-	4.37E-01	4.23E-01	2.48E-02	5.30E-03
	4.37E-01	-	4.64E-01	4.51E-01	1.71E-02	5.50E-03

	4.64E-01	-	4.91E-01	4.78E-01	9.80E-03	5.60E-03
	4.91E-01	-	5.19E-01	5.05E-01	4.30E-03	5.70E-03
	5.19E-01	-	5.46E-01	5.32E-01	1.00E-03	5.80E-03
						5.35E-02
^{129m}Te						
	0.00E+00	-	7.35E-02	3.68E-02	6.26E-02	0.00E+00
	7.35E-02	-	1.47E-01	1.10E-01	6.87E-02	0.00E+00
	1.47E-01	-	2.21E-01	1.84E-01	7.39E-02	1.00E-04
	2.21E-01	-	2.94E-01	2.57E-01	7.76E-02	2.20E-03
	2.94E-01	-	3.68E-01	3.31E-01	7.97E-02	4.20E-03
	3.68E-01	-	4.41E-01	4.04E-01	8.03E-02	5.20E-03
	4.41E-01	-	5.15E-01	4.78E-01	7.94E-02	5.60E-03
	5.15E-01	-	5.88E-01	5.51E-01	7.66E-02	5.90E-03
	5.88E-01	-	6.62E-01	6.25E-01	7.22E-02	6.10E-03
	6.62E-01	-	7.35E-01	6.98E-01	6.64E-02	6.20E-03
	7.35E-01	-	8.09E-01	7.72E-01	5.95E-02	6.40E-03
	8.09E-01	-	8.82E-01	8.45E-01	5.18E-02	6.50E-03
	8.82E-01	-	9.56E-01	9.19E-01	4.37E-02	6.60E-03
	9.56E-01	-	1.03E+00	9.92E-01	3.56E-02	6.70E-03
	1.03E+00	-	1.10E+00	1.07E+00	2.77E-02	6.80E-03
	1.10E+00	-	1.18E+00	1.14E+00	2.02E-02	6.90E-03

	1.18E+00	-	1.25E+00	1.21E+00	1.33E-02	7.00E-03
	1.25E+00	-	1.32E+00	1.29E+00	7.30E-03	7.10E-03
	1.32E+00	-	1.40E+00	1.36E+00	2.90E-03	7.20E-03
	1.40E+00	-	1.47E+00	1.43E+00	4.99E-04	7.30E-03
						1.04E-01
^{131m}Te						
	0.00E+00	-	1.22E-01	6.08E-02	4.65E-01	0.00E+00
	1.22E-01	-	2.43E-01	1.82E-01	3.08E-01	1.00E-04
	2.43E-01	-	3.65E-01	3.04E-01	1.43E-01	3.90E-03
	3.65E-01	-	4.86E-01	4.26E-01	3.29E-02	5.30E-03
	4.86E-01	-	6.08E-01	5.47E-01	9.10E-03	5.90E-03
	6.08E-01	-	7.30E-01	6.69E-01	6.40E-03	6.20E-03
	7.30E-01	-	8.51E-01	7.91E-01	5.30E-03	6.40E-03
	8.51E-01	-	9.73E-01	9.12E-01	4.90E-03	6.60E-03
	9.73E-01	-	1.09E+00	1.03E+00	4.40E-03	6.80E-03
	1.09E+00	-	1.22E+00	1.16E+00	3.90E-03	6.90E-03
	1.22E+00	-	1.34E+00	1.28E+00	3.40E-03	7.10E-03
	1.34E+00	-	1.46E+00	1.40E+00	3.00E-03	7.20E-03
	1.46E+00	-	1.58E+00	1.52E+00	2.70E-03	7.30E-03
	1.58E+00	-	1.70E+00	1.64E+00	2.30E-03	7.50E-03
	1.70E+00	-	1.82E+00	1.76E+00	2.00E-03	7.60E-03

	1.82E+00	-	1.95E+00	1.89E+00	1.60E-03	7.70E-03
	1.95E+00	-	2.07E+00	2.01E+00	1.10E-03	7.80E-03
	2.07E+00	-	2.19E+00	2.13E+00	6.76E-04	7.90E-03
	2.19E+00	-	2.31E+00	2.25E+00	3.05E-04	8.00E-03
	2.31E+00	-	2.43E+00	2.37E+00	4.93E-05	8.10E-03
						1.24E-01
132Te						
	0.00E+00	-	1.08E-02	5.40E-03	1.22E-01	0.00E+00
	1.08E-02	-	2.15E-02	1.61E-02	1.13E-01	0.00E+00
	2.15E-02	-	3.23E-02	2.69E-02	1.05E-01	0.00E+00
	3.23E-02	-	4.30E-02	3.77E-02	9.64E-02	0.00E+00
	4.30E-02	-	5.38E-02	4.84E-02	8.80E-02	0.00E+00
	5.38E-02	-	6.45E-02	5.92E-02	7.96E-02	0.00E+00
	6.45E-02	-	7.53E-02	6.99E-02	7.14E-02	0.00E+00
	7.53E-02	-	8.60E-02	8.07E-02	6.33E-02	0.00E+00
	8.60E-02	-	9.68E-02	9.14E-02	5.54E-02	0.00E+00
	9.68E-02	-	1.08E-01	1.02E-01	4.77E-02	0.00E+00
	1.08E-01	-	1.18E-01	1.13E-01	4.03E-02	0.00E+00
	1.18E-01	-	1.29E-01	1.24E-01	3.33E-02	0.00E+00
	1.29E-01	-	1.40E-01	1.35E-01	2.68E-02	0.00E+00
	1.40E-01	-	1.51E-01	1.45E-01	2.08E-02	0.00E+00

	1.51E-01	-	1.61E-01	1.56E-01	1.53E-02	1.17E-05
	1.61E-01	-	1.72E-01	1.67E-01	1.06E-02	3.27E-05
	1.72E-01	-	1.83E-01	1.78E-01	6.60E-03	5.38E-05
	1.83E-01	-	1.94E-01	1.88E-01	3.50E-03	7.50E-05
	1.94E-01	-	2.04E-01	1.99E-01	1.30E-03	9.59E-05
	2.04E-01	-	2.15E-01	2.10E-01	2.48E-04	4.62E-04
						7.31E-04
170Tm						
	0.00E+00	-	4.84E-02	2.42E-02	8.30E-02	0.00E+00
	4.84E-02	-	9.68E-02	7.26E-02	8.42E-02	0.00E+00
	9.68E-02	-	1.45E-01	1.21E-01	8.45E-02	0.00E+00
	1.45E-01	-	1.94E-01	1.69E-01	8.38E-02	0.00E+00
	1.94E-01	-	2.42E-01	2.18E-01	8.21E-02	8.00E-04
	2.42E-01	-	2.90E-01	2.66E-01	7.95E-02	2.60E-03
	2.90E-01	-	3.39E-01	3.15E-01	7.60E-02	4.00E-03
	3.39E-01	-	3.87E-01	3.63E-01	7.16E-02	4.70E-03
	3.87E-01	-	4.36E-01	4.11E-01	6.63E-02	5.30E-03
	4.36E-01	-	4.84E-01	4.60E-01	6.04E-02	5.50E-03
	4.84E-01	-	5.32E-01	5.08E-01	5.37E-02	5.80E-03
	5.32E-01	-	5.81E-01	5.57E-01	4.66E-02	5.90E-03
	5.81E-01	-	6.29E-01	6.05E-01	3.91E-02	6.10E-03

	6.29E-01	-	6.78E-01	6.53E-01	3.14E-02	6.10E-03
	6.78E-01	-	7.26E-01	7.02E-01	2.38E-02	6.20E-03
	7.26E-01	-	7.74E-01	7.50E-01	1.66E-02	6.30E-03
	7.74E-01	-	8.23E-01	7.99E-01	1.02E-02	6.40E-03
	8.23E-01	-	8.71E-01	8.47E-01	5.10E-03	6.50E-03
	8.71E-01	-	9.20E-01	8.95E-01	1.90E-03	6.60E-03
	9.20E-01	-	9.68E-01	9.44E-01	3.28E-04	6.70E-03
						8.55E-02
91Y						
	0.00E+00	-	7.71E-02	3.86E-02	5.64E-02	0.00E+00
	7.71E-02	-	1.54E-01	1.16E-01	6.16E-02	0.00E+00
	1.54E-01	-	2.31E-01	1.93E-01	6.57E-02	1.00E-04
	2.31E-01	-	3.09E-01	2.70E-01	6.84E-02	2.70E-03
	3.09E-01	-	3.86E-01	3.47E-01	7.00E-02	4.50E-03
	3.86E-01	-	4.63E-01	4.24E-01	7.07E-02	5.30E-03
	4.63E-01	-	5.40E-01	5.02E-01	7.05E-02	5.70E-03
	5.40E-01	-	6.17E-01	5.79E-01	6.96E-02	6.00E-03
	6.17E-01	-	6.94E-01	6.56E-01	6.79E-02	6.20E-03
	6.94E-01	-	7.72E-01	7.33E-01	6.56E-02	6.30E-03
	7.72E-01	-	8.49E-01	8.10E-01	6.24E-02	6.50E-03
	8.49E-01	-	9.26E-01	8.87E-01	5.83E-02	6.60E-03

	9.26E-01	-	1.00E+00	9.64E-01	5.32E-02	6.70E-03
	1.00E+00	-	1.08E+00	1.04E+00	4.69E-02	6.80E-03
	1.08E+00	-	1.16E+00	1.12E+00	3.95E-02	6.90E-03
	1.16E+00	-	1.23E+00	1.20E+00	3.11E-02	7.00E-03
	1.23E+00	-	1.31E+00	1.27E+00	2.21E-02	7.10E-03
	1.31E+00	-	1.39E+00	1.35E+00	1.33E-02	7.20E-03
	1.39E+00	-	1.47E+00	1.43E+00	5.70E-03	7.20E-03
	1.47E+00	-	1.54E+00	1.50E+00	9.32E-04	7.30E-03
						1.06E-01
95Zr						
	0.00E+00	-	4.44E-02	2.22E-02	2.36E-01	0.00E+00
	4.44E-02	-	8.87E-02	6.66E-02	2.11E-01	0.00E+00
	8.87E-02	-	1.33E-01	1.11E-01	1.81E-01	0.00E+00
	1.33E-01	-	1.77E-01	1.55E-01	1.45E-01	0.00E+00
	1.77E-01	-	2.22E-01	2.00E-01	1.07E-01	1.00E-04
	2.22E-01	-	2.66E-01	2.44E-01	6.90E-02	1.70E-03
	2.66E-01	-	3.11E-01	2.88E-01	3.56E-02	3.40E-03
	3.11E-01	-	3.55E-01	3.33E-01	1.18E-02	4.30E-03
	3.55E-01	-	3.99E-01	3.77E-01	1.70E-03	4.90E-03
	3.99E-01	-	4.44E-01	4.21E-01	4.34E-04	5.30E-03
	4.44E-01	-	4.88E-01	4.66E-01	4.11E-04	5.50E-03

	4.88E-01	-	5.32E-01	5.10E-01	3.79E-04	5.80E-03
	5.32E-01	-	5.77E-01	5.55E-01	3.41E-04	5.90E-03
	5.77E-01	-	6.21E-01	5.99E-01	2.96E-04	6.00E-03
	6.21E-01	-	6.65E-01	6.43E-01	2.45E-04	6.10E-03
	6.65E-01	-	7.10E-01	6.88E-01	1.89E-04	6.20E-03
	7.10E-01	-	7.54E-01	7.32E-01	1.32E-04	6.30E-03
	7.54E-01	-	7.99E-01	7.76E-01	7.81E-05	6.40E-03
	7.99E-01	-	8.43E-01	8.21E-01	3.27E-05	6.50E-03
	8.43E-01	-	8.87E-01	8.65E-01	5.79E-06	6.50E-03
						8.09E-02

APPENDIX E INHALATION DOSE RATE CONVERSION FACTORS

Radionuclide	Dp_InhDP (mrem*m^2 µCi^{-1})	DRCF @ 1m (mrem m^2 µCi^{-1} hr^{-1})	DRCF @ 40cm (mrem m^2 µCi^{-1} hr^{-1})	DRCF @ 20cm (mrem m^2 µCi^{-1} hr^{-1})
^{241}Am	2.80E+02	2.92E+00	4.14E+00	5.33E+00
^{140}Ba	1.90E-02	1.98E-04	2.81E-04	3.62E-04
^{141}Ce	1.00E-02	1.04E-04	1.48E-04	1.90E-04
^{144}Ce	1.50E-01	1.60E-03	2.20E-03	2.90E-03
^{252}Cf	1.10E+02	1.15E+00	1.63E+00	2.09E+00
^{242}Cm	1.70E+01	1.77E-01	2.52E-01	3.24E-01
^{244}Cm	1.60E+02	1.67E+00	2.37E+00	3.05E+00
^{60}Co	8.80E-02	9.17E-04	1.30E-03	1.70E-03
^{134}Cs	5.80E-02	6.04E-04	8.58E-04	1.10E-03
^{136}Cs	7.20E-03	7.50E-05	1.07E-04	1.37E-04
^{137}Cs	1.10E-01	1.10E-03	1.60E-03	2.10E-03
^{153}Gd	6.80E-03	7.08E-05	1.01E-04	1.30E-04
^{129}I	1.00E-01	1.00E-03	1.50E-03	1.90E-03
^{131}I	1.80E-02	1.88E-04	2.66E-04	3.43E-04
^{132}I	1.30E-05	1.35E-07	1.92E-07	2.48E-07
^{133}I	1.30E-03	1.35E-05	1.92E-05	2.48E-05
^{134}I	2.40E-06	2.50E-08	3.55E-08	4.57E-08

^{135}I	1.00E-04	1.04E-06	1.48E-06	1.90E-06
^{192}Ir	1.90E-02	1.98E-04	2.81E-04	3.62E-04
^{140}La	1.70E-03	1.77E-05	2.51E-05	3.24E-05
^{99}Mo	1.90E-03	1.98E-05	2.81E-05	3.62E-05
^{95}Nb	4.80E-03	5.00E-05	7.10E-05	9.14E-05
^{237}Np	9.60E+02	1.00E+01	1.42E+01	1.83E+01
^{239}Np	1.80E-03	1.88E-05	2.66E-05	3.43E-05
^{147}Pm	2.00E-02	2.08E-04	2.96E-04	3.81E-04
^{238}Pu	3.10E+02	3.23E+00	4.59E+00	5.90E+00
^{239}Pu	3.40E+02	3.54E+00	5.03E+00	6.48E+00
^{241}Pu	6.60E+00	6.87E-02	9.76E-02	1.26E-01
^{226}Ra	5.40E+01	5.63E-01	7.99E-01	1.03E+00
^{103}Ru	7.80E-03	8.13E-05	1.15E-04	1.49E-04
^{106}Ru	1.80E-01	1.90E-03	2.70E-03	3.40E-03
^{127}Sb	3.70E-03	3.85E-05	5.47E-05	7.05E-05
^{129}Sb	3.40E-05	3.54E-07	5.03E-07	6.48E-07
^{75}Se	3.70E-03	3.85E-05	5.47E-05	7.05E-05
^{89}Sr	2.10E-02	2.19E-04	3.11E-04	4.00E-04
^{90}Sr	4.40E-01	4.60E-03	6.50E-03	8.40E-03
^{91}Sr	2.40E-04	2.50E-06	3.55E-06	4.57E-06
^{129m}Te	2.10E-02	2.19E-04	3.11E-04	4.00E-04

^{131m}Te	2.80E-03	2.92E-05	4.14E-05	5.33E-05
^{132}Te	3.70E-03	3.85E-05	5.47E-05	7.05E-05
^{170}Tm	2.50E-02	2.60E-04	3.70E-04	4.76E-04
^{91}Y	2.40E-02	2.50E-04	3.55E-04	4.57E-04
^{169}Yb	7.80E-03	8.13E-05	1.15E-04	1.49E-04
^{95}Zr	2.60E-02	2.71E-04	3.85E-04	4.95E-04